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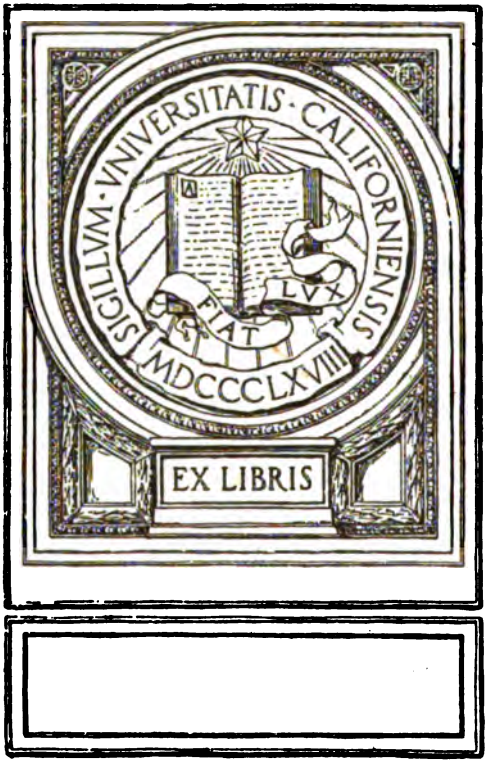
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FOR

AGRICULTURAL STUDENTS, LAND AGENTS AND FARMERS

BY

A. H. HAINES, P.A.S.I.

HEAD OF THE ESTATE MANAGEMENT DEPARTMENT AND LECTURER IN SURVEYING
AT THE SOUTH EASTERN AGRICULTURAL COLLEGE, WYE, KENT
MEMBER OF THE BOARD OF STUDIES IN AGRICULTURE OF LONDON UNIVERSITY

AND

A. F. HOOD DANIEL

LECTURER IN BUILDING CONSTRUCTION
AT THE SOUTH EASTERN AGRICULTURAL COLLEGE, WYE, KENT

WITH ILLUSTRATIONS

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PREFACE

THIS book starts upon its career with a distinctly modest purpose—namely, to give very practical aid to Agricultural Students, Land Agents, and Farmers in the every-day tasks of Surveying and Building Construction. Although the great value of many text-books upon these separate subjects and upon Farm Buildings alone is undeniable, for the most part they are too long and too advanced for any but those who intend to make one of these subjects their profession.

It is hoped, also, that this work, divided as it is under the two sections, will be found useful to those who intend to pass the Professional Examinations of the Surveyors' Institution. It must, however, be remembered that no amount of reading can take the place of practice. The mere study of the latest works on Golf will not enable one to drive like Braid, or to accomplish a Vardon-like approach-shot. The celebrated advice of Mr. Squeers of Dotheboys Hall, who taught his pupils how to spell 'clean' and 'winder' and then sent them to 'go and do it,' may here come in useful. This sensible combination of theory and practice (out of the mouth of a very much misunderstood genius) may be confidently recommended to the Agricultural Student.

The Authors wish to acknowledge their indebtedness for referential purposes to N. Mitra's 'Manual of Surveying'; Baker and Dixon's 'Surveying'; 'Surveying,' by J. Whitelaw, Jun.; N. F. Mackenzie's 'Methods of Surveying'; 'The Practical Surveyor' and 'Levelling,' by Thomas Holloway; Stanley's 'Surveying Instruments'; Hiley's 'Mensuration'; Bright's 'Agricultural Valuer's Assistant'; C. E. Curtis's 'Estate Management'; Rivington's 'Notes on Building Construction'; and Charles F. Mitchell's 'Building Construction.'

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Thanks are especially due to Messrs. A. G. Thornton Ltd. of Manchester for their help and kindness in supplying the engravings of instruments in Part I; and to Mr. S. Rothwell, N.D.A., M.S.E.A.C., of Wye Agricultural College, for his agricultural advice in connection with the Plans of Farm Buildings for a 400-acre farm and a small holding.

With the exception of the Dutch Barn all the illustrations in Part II are from original drawings by A. F. Hood Daniel.

A. H. HAINES.
A. F. HOOD DANIEL.

Wye, Kent.
1915.

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PART I

SURVEYING

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CHAPTER I

MENSURATION

RULES for the calculation of areas :—

1. To find the area of a **Triangle.**

Multiply the base by the *perpendicular* and divide by 2.

If, however, the perpendicular be not given and not obtainable, and all three sides be known then, supposing s = the semi-perimeter (i.e. half the sum of the sides) and the sides be respectively a, b, c :—

$$\text{Area} = \sqrt{s(s-a)(s-b)(s-c)}$$

2. To find the area of a **Parallelogram.**

Multiply the length of one side by the perpendicular distance from it to the other side.

3. To find the area of a **Trapezoid** (i.e. a four-sided figure having two of its sides parallel).

Add together the two parallel sides and multiply by the perpendicular distance between them and divide by 2.

4. To find the area of a **Trapezium** (i.e. any irregular four-sided figure).

Multiply the diagonal which joins the two opposite angles by the sum of the perpendiculars from the other two angles to this diagonal and divide by 2.

5. To find the area of any **Polygon** (i.e. a plane figure bounded by a number of straight lines).

Divide the figure into triangles by means of straight lines drawn from its angles. Calculate the area of each triangle by Rule 1 and add the results.

6. To find the area of a **Circle.**

(*a*) Multiply the square of the radius by 3·1416. Formula πr^2 (π or *pi*, Greek letter p = 3·1416 or $\frac{22}{7}$ and r = radius).

(*b*) Multiply the square of the diameter by $\frac{11}{14}$ or 0·785.

(*c*) Multiply the square of the circumference by $\frac{7}{88}$ or 0·0796. The circumference = $2\pi r$.

Rules for the Calculation of the Volumes of Solids

1. **The Cube** (i.e. a solid bounded by six equal square faces).

$$Volume = (\text{side})^3$$

2. **The Rectangular Parallelopiped** (i.e. a solid bounded by six rectangular faces, each of them being equal and parallel to its opposite face).

$$Volume = \text{Length} \times \text{breadth} \times \text{height}$$

3. **The Right Prism and the Right Cylinder.**—A Prism is a solid whose two ends are similar, equal, and parallel plane rectilineal figures, and whose side faces are parallelograms. The line drawn from the *centre* of *one* end to the *centre* of the *other* end is called the *axis* of the prism. In a *right prism* the axis is at right angles to the ends of the prism. In an *oblique prism* the axis is not at right angles to the ends.

A *Cylinder* is a solid which has its ends two equal and parallel circles. The axis of the *right cylinder* is perpendicular to the ends, and the axis of the oblique cylinder is not perpendicular to the ends.

$$Volume = \text{Area of base} \times \text{height}$$

4. **The Right Pyramid and the Right Cone.**—A pyramid is a solid having any plane rectilineal figure for its base and triangles for its sides, all of which terminate in one common point, called the vertex.

A right pyramid is a pyramid in which the straight line drawn from the vertex to the centre of the base is perpendicular to the base.

A cone is a solid which has its base circular and whose curved surface terminates in a point called the vertex. In a right cone the axis is perpendicular to the base.

$$Volume = \frac{\text{Area of base} \times \text{perpendicular height}}{3}$$

5. **The Prismoid or Frustum of a Wedge.**—A prismoid, or frustum of a wedge, is the solid which remains after a smaller wedge has been cut off by a plane parallel to the base.

$$Volume = (\text{Area of top} + \text{area of bottom} + \text{four times the area of the middle section}) \times \text{height} \times \tfrac{1}{6}$$

6. **The Sphere** (i.e. a solid circle).

$$Volume = (\text{Diameter})^3 \times \tfrac{1}{6}\tfrac{1}{6}$$

TABLES

Linear Measure

Inches	Links	Feet	Yards	Poles	Chains	Furlongs	Mile
7·92	1						
12	1·515	1					
36	4·545	3	1				
198	25	16·5	5·5	1			
792	100	66	22	4	1		
7,920	1000	660	220	40	10	1	
63,360	8000	5280	1760	320	80	8	1

A knot, or nautical mile, is the length of one minute of a degree of latitude at mean sea level. Its length varies in different latitudes from about 6,107 feet at the poles to 6,045 feet at the equator. Mean value = 6,076 feet or 1·15 statute miles approximately.

Square Measure

Sq. Inches	Sq. Links	Sq. Feet	Sq. Yards	Sq. Perches	Sq. Chains	Roods	Acres	Sq. Mile
144	2·295	1						
1,296	20·661	9	1					
39,204	625	272·25	30·25	1				
627,264	10,000	4,356	484	16	1			
1,568,160	25,000	10,890	1210	40	2·5	1		
6,272,640	100,000	43,560	4840	160	10	4	1	
——	64,000,000	27,878,400	3,097,600	102,400	6,400	2,560	640	1

Cubic Measure

Cubic Inches	Cubic Feet	Cubic Yard
1,728	1	
46,656	27	1

The sides of a square containing an acre are 69½ yards or 208·71 feet.

Liquid Measure

Gills	Pints	Quarts	Gallon
4	1		
8	2	1	
32	8	4	1

One gallon = 277·463 cubic inches.

Dry Measure

Gallons	Pecks	Bushels	Quarter
2	1		
8	4	1	
64	32	8	1

The standard bushel contains 2,219·7 cubic inches.

Avoirdupois Weight

Drams	Oz.	Lb.	Stones	Quarters	Cwt.	Tons
16	1					
256	16	1				
3,584	224	14	1			
7,168	448	28	2	1		
28,672	1,792	112	8	4	1	
573,440	35,840	2240	160	80	20	1

This is used for all general purposes. Troy weight is used only for gold, silver, and jewellery.

Hay and Straw Measure

1 Truss of Straw = 36 lb.
1 Truss of old Hay = 56 lb. (sold after August 31).
1 Truss of new Hay = 60 lb. (sold between June 1 and August 31).
1 Load of Straw = 36 trusses = 11 cwt. 2 qr. 8 lb.
1 Load of old Hay = 36 ,, = 18 cwt. 0 qr. 0 lb.
1 Load of new Hay = 36 ,, = 19 cwt. 1 qr. 4 lb.

Miscellaneous

1 cubic foot of water = 62·425 lb. = 6·235 gallons.
1 cubic inch of water = 0·03612 lb.
1 Imperial gallon of water = 10 lb.
1 ton of water = 35·94 cubic feet = 224 gallons.
1 inch of rainfall = 3,630 cubic feet per acre.
,, = 101·1 tons per acre.
,, = 22,635 Imperial gallons per acre.

One man in a day of 10 hours should dig and barrow, about :—

Easily got earth . . . 12 cubic yards
Strong clay . . . . 9 cubic yards
Hard earth or chalk . . 7 cubic yards

Number of Cubic Feet of Various Earths in One Ton

Loose earth	24	Earth with gravel	18
Clay	18½	Common soil	15½
Coarse sand or gravel	18½	Clay with gravel	14½

Percentage.—To express one number as the percentage of another, multiply the number by 100 and divide the product by the other number.

Specific Gravities

Water	= 1	Cast iron	= 7·207
Milk	= 1·03	Wrought iron	= 7·788
Earth (loose)	= 1·50	Steel	= 7·82
Sand	= 1·4–1·6	Lead	= 11·388
Clay	= 1·8–2·6	Zinc	= 7·192
Unslaked Lime	= 1·85	Copper	= 8·9
Brick	= 1·40	Brass	= 8·4
Limestone	= 2·66	Diamond	= 3·5
Chalk	= 2·75	Gold	= 19·3
Coal	= 1·2–1·7	Glass	= 2·4–3·4
Granite	= 2·5–2·9	Silver	= 10·6
Oak (Green)	= 1·08	Elm (Green)	= 0·932
Oak (Dry)	= 0·708	Elm (Dry)	= 0·550
Ash (Green)	= 0·905	Beech (Green)	= 1·05
Ash (Dry)	= 0·644	Beech (Dry)	= 0·696

Rule for finding the weight of a body when its specific gravity is given:—Multiply its specific gravity by 62·5 (number of pounds of water in a cubic foot) and the result equals its weight per cubic foot in pounds Avoirdupois.

Metric System

Long Measure compared with English Units

	Metres	Inches	Feet	Yards	Miles
Millimetre	·001	·03937	·00328	·00109	—
Centimetre	·01	·3937	·0328	·0109	—
Decimetre	·1	3·937	·328	·1093	·00006
Metre	1	39·37079	3·2809	1·0936	·00062
Decametre	10	—	32·809	10·9363	·00621
Hectometre	100	—	328·09	109·363	·06213
Kilometre	1000	—	3280·9	1093·63	·62138
Myriametre	10000	—	—	—	6·21382

Square Measure compared with English Units

	Square Metres	Square Inches	Square Feet	Square Yards	Acres
Milliare . .	·1	155	1·076	·119	—
Centiare . .	1	1,550	10·764	1·19	·00025
Deciare . .	10	15,501	107·64	11·96	·0025
Are . . .	100	—	1076·4	119·6	·0247
Decare . .	1000	—	—	1196	·2471
Hectare . .	10000	—	—	11960	2·4711

Solid Measure compared with English Units

	Cubic Metres	Cubic Inches	Cubic Feet	Cubic Yards
Millistere . .	·001	61·028	—	—
Centistere . .	·01	610·28	·353	—
Decistere . .	·1	6102·8	3·531	·130
Stere . . .	1	61028	35·317	1·308
Decastere . .	10	—	—	13·080
Hectostere . .	100	—	—	130·802

Weights compared with English Units

	Grammes.	Avoir. oz.	Avoir. lb.	Cwt.	Tons	Grains ℔ Troy
Milligramme .	·001	—	—	—	—	·015
Centigramme .	·01	—	—	—	—	·154
Decigramme .	·1	—	—	—	—	1·543
Gramme . .	1	·035	·0022	—	—	15·432
Decagramme .	10	·352	·022	—	—	—
Hectogramme .	100	3·527	·2204	—	—	—
Kilogramme .	1000	35·274	2·2046	·019	·00098	—
Myriogramme .	10000	—	22·046	·196	·00984	—
Quintal . .	100000	—	220·462	1·968	·0984	—
Millier . .	1000000	—	2204·62	19·684	·9842	—

Dry and Fluid Measure compared with English Units

	Litres	Cu. Inches	Cu. Feet	Gallons	Bushels
Millilitre . .	·001	·061	—	·00022	—
Centilitre . .	·01	·61	—	·0022	—
Decilitre . .	·1	6·1	—	·022	·0027
Litre . .	1	61·02	·0353	·22	·0275
Decalitre . .	10	610·28	·353	2·2	·275
Hectolitre . .	100	—	3·53	22	2·751
Kilolitre . .	1000	—	35·317	220·09	27·512
Myrialitre . .	10000	—	353·17	2200·9	275·121

Land is usually measured in Ares, and volume in Litres. One litre = about 1¾ pints.

To ascertain the surface of a common 'barge' roof (i.e. a roof in the shape of a book when partially opened).

Rule :—Length in feet × breadth in feet × 2 ÷ 100 = *the number of squares.*

Thatching and tiling are reckoned by the 'square,' i.e. 100 square feet.

To ascertain the surface of a hip-roof (i.e. a roof similar to the last but having its topmost corners cut off in such a way that a further triangular roof is required at the ends, the ends rising immediately from the wall and having the same inclination to the horizon as the sides have).

Rule :—Mean length in feet × breadth in feet = *the surface of one side.* Length in feet of the end × length in feet of the perpendicular distance from the eaves of the end to the ridge ÷ 2 = *the surface of the end.* These two results added together × 2 ÷ 100 = *the number of squares.*

To ascertain the surface of a circular roof.

Rule :—Measure the distance from the eaves to the point and proceed according to the rules for finding the area of circles. The result will be twice the area of the roof, so that it must be divided by 2 and again by 100 to obtain the number of squares.

To ascertain the area of brickwork.—Brickwork is reckoned by the rod of 272 square feet and varies in cost from £14 to £17 per rod.

Rule :—Length in feet × height in feet ÷ 272 = *number of rods of brickwork.*

A rod of brickwork is, however, always calculated to be 14 inches thick, so that if the wall is only 9 inches thick take two-thirds of the result, and if only 4½ inches thick take one-third for the answer. When measuring buildings calculate the whole surface of the wall and deduct the door and window spaces afterwards.

To ascertain the capacity of tanks.

Rule :—Oblong or square tanks—Length in feet × breadth in feet × depth in feet × 6·235 = *the number of gallons.*

Circular tanks—(Mean diameter)^2 × 0·7854 × depth × 6·235 = *the number of gallons.*

To ascertain the contents of ash and sand heaps.—Ash and sand heaps are generally in the shape of a cone. The former are generally considered in bushels and the latter in yards. There are about 17 bushels of ashes to a cubic yard.

Rule :—

[(Circumference in feet of base)^2 × 0·0796 × perpendicular height in feet] ÷ (3 × 27) = *the number of cubic yards.*

To ascertain the weight of cattle.—Measure the girth of the animal immediately behind the shoulder and the length from the square of the shoulder to the tail-head.

Rule :— $\frac{(\text{Girth in feet})^2 \times \text{length} \times 5}{21}$ = the net weight of the

animal in Imperial stones of 14 lb. A butcher's or Smithfield stone = 8 lb.

If 30 is substituted for 21 then the weight will be in scores. If the beast is very fat one-fifteenth should be added to the weight so obtained: if not moderately fat one-fifteenth should be deducted.

Live and Dead Weight of Animals

Bullock.	Dead weight of	Lean	Beast	50	per cent. of	Live	weight
	,,	,,	,, Fat	,,	60	,,	,,	,,
Sheep.	,,	,,	,, Lean	,,	50	,,	,,	,,
	,,	,,	,, Fat	,,	56	,,	,,	,,
Pigs.	,,	,,	. . .		80 per cent.			

To ascertain the contents of dung heaps.—Measure the length, width and depth in feet wherever the inequalities of the heap render it necessary and take the mean of each.

Rule :—

(Length in feet × width in feet × depth in feet) ÷ 27 = *number of cubic yards*

It is required to manure a field with farm-yard dung at the rate of 15 tons per acre, each heap to contain 3 cwt.: at what distance apart should the heaps be placed?

There are therefore 100 heaps: 4840 ÷ 100 = 48·4. Square root of 48·4 = (say) 7. The heaps will be 7 yards apart.

To estimate the cost of draining agricultural land.—Reduce all items to lineal rods. The number of rods of minor drains required per acre may be found by dividing 2640 by the distance apart in feet at which it is intended to lay the drains. The number of pipes (12 inches long) required is obtained by multiplying the number of rods by 16·5.

The number of pipes for the mains must be arrived at by measurement on the ground or the map.

Example.—It is required to drain a 5-acre field with 2½-inch pipes 21 feet apart, 3 feet deep. The main is 660 feet long and 4-inch pipes are used.

$$\text{Number of rods} = 5 \text{ (number of acres)} \times \frac{2640}{21} = \text{(say) } 629 \text{ rods.}$$

	£	s.	d.
Labour of cutting, filling and pipe laying 629 rods at 6*d.* =	15	14	6
Number of pipes required = 629 × 16·5 = 10378: allowing for breakages (say) 10400 2½-inch pipes at 30*s.* per 1000 . . . . . =	15	12	0
Main 40 rods, labour at 8*d.* per rod . . . =	1	6	8
Number of pipes required for main = 40 × 16·5 = 660, (say) 700 4-inch pipes at 45*s.* per 1000 . . =	1	11	6
Outlet (say) . . . . . =	1	0	0
	£35	4	8

This is equal to about £7 per acre, and depreciation may be taken at 4 per cent. per annum.

To ascertain the contents of timber.—There are five systems of measurement, known as :—

1. *The die square* which represents the cubic contents obtained by multiplying the length by the area of the inscribed square at the centre of the butt.

2. *Calliper measure* in which the area of the circumscribed square is the basis of calculation.

3. *True contents*, for which the sectional area at the centre and the length are the factors. (Used by Continental Foresters.)

4. *Board measure* by which the contents are reckoned according to the number of superficial feet of one-inch boards which can be cut out of a log—allowance for bark, &c., being made. (Used in America.)

5. *Quarter-girth* in which the contents are taken as the product of the length and the square of one-quarter of the circumference at the centre. (Used in Great Britain.)

In England we adopt the last-mentioned system of measurement. It is a compromise between the vendor who would naturally favour the true contents method and the purchaser who would prefer die square measurement, maintaining that he can only cut square timber out of the latter measurement. The quarter-girth system, then, distributes the waste, so to speak, between vendor and purchaser, which is a fair and equitable arrangement.

Rule :—

$$\frac{(\frac{1}{4}\text{ girth in inches})^2 \times \text{length in feet}}{144} = \textit{the cubic contents in feet.}$$

For *die square* substitute 181 for 144 as a divisor in the above formula, and for *true contents* 113. For *calliper measure* substitute (mean diameter in inches)^2 for ($\frac{1}{4}$ girth in inches)^2. For *board measure* the following rule may be used when the log does not exceed 40 feet in length :—Take the mean diameter in inches at the small end of the log, and deduct $1\frac{1}{2}$ inches from it : the result squared $\times$ 0·785 = the sectional area at small end. Then—

$$\frac{(\text{Sectional area} - \frac{3}{11}\text{ sectional area}) \times \text{length of log in feet}}{12}$$

= the number of feet super., board measure.

It should be borne in mind that if we wish to compare Continental prices with British we must raise the former by about one-third in consequence of the different system of measurement, because quarter-girth is about 25 per cent. less than true contents.

Method of Measuring Standing Timber.—*To obtain the height.*—The usual way is to have a pole marked off in feet held against the trunk. This pole may be of ash, cut from the wood, say 15 feet long. Held at arm's length it will give a height of about 22 feet. The remainder must be estimated by the eye. Bamboo rods which fit in lengths like a fishing-rod are sold for the purpose. These are about 25 feet in length and if held at arm's length will reach a height of about 32 feet.

If the height is required to be known accurately, a very useful instrument for the purpose is the Apomecometer which is explained in a later chapter.

To estimate the girth.—This is usually taken at about 4 to 5 feet from the ground with a strap made for the purpose and called a timber measuring strap. This strap gives at once the quarter-girth in inches, whereas if an ordinary tape is used the girth in inches must be divided by 4. A good strap for the purpose is an old and well-worn driving rein about 12 feet long with a hook at one end. In using, it should be stretched as tight as possible, and therefore in marking the sizes it should also be stretched tight.

But in measuring the girth there are two things of great importance to be considered. Firstly, the thickness of the bark must be estimated; it is usual to allow one inch in every twelve inches of quarter-girth for rough-barked trees, and half-inch in every twelve inches of quarter-girth for smooth-barked trees. In the case of beech trees no allowance is made as a rule for bark.

Secondly, a further allowance must be made for 'taper' or 'fall off' (i.e. the tree getting thinner at the top of the stem). Anything under 6 inches quarter-girth is not considered, so that the height is calculated up to where this quarter-girth is estimated to be. It is obvious that when measuring at 5 feet from the ground the average quarter-girth is not obtained, and the allowance for this discrepancy is generally, in normally shaped trees, one inch in quarter-girth for every 10 feet in height for Conifers and about $1\frac{1}{2}$ inches in 10 feet for broad-leaved trees. Such an allowance is admittedly somewhat arbitrary and only experience can give correct results. These three methods may be given for getting at the average girth of standing timber:—

1. Measure at 5 feet from the ground, then estimate the measurement 5 feet from the top, and average.
2. Estimate the girth at the centre of the tree.
3. Measure at 5 feet and deduct one inch for every 10 feet of height.

Many practical men prefer method No. 1. It has the advantage over No. 2 in that the error in the estimated measurement is corrected to the extent of one-half by averaging with the actual measurement. No. 3, in the case of trees such as larch and spruce which may be nearly cylindrical and of great length, favours the buyer too much.

There are various customs as to what is to be measured for timber and the Kentish practice is to measure only the spire and give the branches against the labour: but it is a bad custom. It is far better to measure everything that is timber and then allow 6*s.* to 7*s.* per 100 cubic feet for the labour of cutting.

Method of Measuring Felled Timber.—It is obviously easier to arrive at correct measurements when the timber is on the ground, and it is consequently better, when selling, to agree at a price per foot and then measure the number of feet when felled.

Take the length with a three-foot rule and mark half the length on the tree. At this spot take the girth with a piece of whipcord attached to a piece of bent wire which will enable it to be pushed under the trunk easily.

Having measured with the whipcord withdraw it and fold it twice; this gives the quarter girth. Now measure the folded whipcord with the foot rule to the nearest quarter of an inch. Deduct the bark allowance. If the tree is irregular in shape, measure each part separately (dividing it into several logs) and add them together. Care should be taken to put the cord straight round the tree and not obliquely.

In working out the formula given the cubic content should be given in feet and inches, and in arriving at the number of inches it should be borne in mind that an inch in this case is the twelfth part of a cubic foot and NOT a cubic inch, which is $\frac{1}{1728}$th part of a cubic foot.

Example.—A tree has a girth of 40 inches under bark and a length of 30 feet.

The quarter girth = 10 inches therefore.

$$\text{Cubic contents} = \frac{10^2 \times 30}{144} = \frac{100 \times 30}{144} = \frac{3000}{144}$$

$$= 20\frac{5}{6} \text{ cubic feet.} \quad \frac{5}{6} \times 12 = 10 \text{ inches.}$$

Therefore the cubic content of the tree is 20 feet 10 inches.

Timber measurer's tables may be obtained from the *Estates Gazette*, price 3*d*., which will obviate the necessity of working out the contents.

34	cubic feet	of	English oak timber	(green)	= 1 ton.
34	,,	,,	beech timber	,,	= 1 ,,
39	,,	,,	elm ,,	,,	= 1 ,,
40	,,	,,	ash ,,	,,	= 1 ,,

On a rough average pieces of timber vary within the following limits per cubic foot according to the quality and size of the timber:—

Oak, 1*s*. to 2*s*. 6*d*.; ash, 1*s*. to 2*s*.; elm, beech, sycamore, sweet chestnut, 9*d*. to 1*s*. 6*d*.; lime, poplar, 9*d*. to 1*s*. 3*d*.; larch, 8*d*. to 1*s*. 2*d*.; Scots pine, 5*d*. to 8*d*.; silver fir, 4*d*. to 6*d*.

Cordwood.—Cordwood consists of those parts of a tree which cannot be called timber and are too big to be classed as faggots. It is made up into stacks of varying sizes according to the custom of the locality. The most usual size is 128 cubic feet of firewood cut into lengths of 2 feet 2 inches. Such a stack would measure 2 feet 2 inches wide, 2 feet 2 inches high, and 27 feet 4 inches long, or 8 feet × 4 feet × 4 feet, and generally sells for about 10*s*.

A *standard* is a measure for converted timber.

To find the number of trees required to plant an acre of land.

Rule :—Divide 43,560 by the square of the distance in feet apart that it is intended to plant the trees, **for square planting.**

Example.—At 4 feet apart : $\frac{43560}{4 \times 4} = 2722$ (approx.).

For triangle planting multiply result by 1·155.

Example.—At 4 feet apart : $\frac{43560}{4 \times 4} \times 1{\cdot}155 = 3144$ (approx.).

To ascertain the contents of Hay Stacks.—*Oblong Stacks.*—Measure the height in feet from the bottom of the stack to the eaves and add to it, if the stack is barge-shaped one-third, if 'hipped' one-quarter of the perpendicular height from the eaves to the ridge for the total height; making an allowance where necessary for bottom or standing of stack.

Measure the length in feet halfway between the eaves and bottom, so as to get the average length; making an allowance for loose outsides—say, 3 or 4 inches in the case of a well-trimmed stack and 6 to 9 in a not well-trimmed stack.

Measure the breadth in feet in the same way as the length. These three measurements multiplied together will give the cubic contents in feet. Divide by 27 to obtain the contents in cubic yards.

The weight of hay per cubic yard in the stack varies considerably, depending on the nature of the hay, its age, the size of the stack, and the part of the stack taken.

The weight may, of course, be accurately ascertained by actual measurement of the cubic contents of a truss, and from this calculating the weight of a cubic foot.

Large ricks are always heavier per cubic yard than small ones; and the round rick is lighter than the oblong one.

The divisors which may be used to obtain the number of tons, when the number of cubic yards has been found, are :—

Not well settled	12
Fairly well settled	10
Very compact	8

Example.—A stack of hay measures 40 feet long, 20 feet wide, and 12 feet high. Find the tonnage.

$40 \times 20 \times 12 = 9600$ cubic feet. Divided by 27 = 355 cubic yards approximately. Putting it at 10 cubic yards to the ton we get 35½ tons of hay in the stack.

Second cut clover hay will require 13 or 14 cubic yards to the ton.

Old hay, when over two years old, deteriorates in value about 20 per cent.; and the difference in price between first, second and third quality may be taken as 20*s*. Thus first (say), 80*s*.; second, 60*s*.; third, 40*s*. per ton.

Consuming price = two-thirds of the market price.

The density of a stack may be arrived at by thrusting in the hand and arm or forcing in a stick. If the stick has a hook on the end

of it, so that some of the interior may be pulled out, the quality can also be judged. If the arm goes in easily the hay may be classed as light and the highest divisor used, but when it does not go far in the hay may be considered heavy.

Round Stacks.—Measure the mean circumference between the bottom and the eaves in feet. Measure the mean height from the bottom to the eaves in feet and add one-quarter of the perpendicular height from the eaves to the point. Then the circumference squared multiplied by 0·08 multiplied by the height = the cubic contents in feet. Divide by 27 to obtain cubic yards, and use the following divisors to obtain tons.

Not well settled	13
Fairly well settled	11
Very compact	9

Example.—A circular stack has an average circumference of 60 feet and a height of 12 feet.

Then $60^2 \times 0{\cdot}08 \times 12 = 3456$ cubic feet = 128 cubic yards. Putting it at 11 cubic yards to the ton we get 11 tons 13 cwt. (approximately).

Hay is sold by the ton in most parts of England, but in the North the basis of calculation is the Imperial stone of 14 lb. Again, in the neighbourhood of London it is sold by the load of 18 cwt. (i.e. 36 trusses weighing 56 lb. each); but when new hay is sold before September 1, the trusses must weigh 60 lb. = 19 cwt. 1 qr. 4 lb. per load (see Tables of Hay and Straw Measure).

To ascertain the contents of Straw Stacks.—Take the measurements in the same way as described for hay stacks.

Taken on an average 18 to 20 cubic yards may be allowed to the ton for wheat, and 20 to 23 for barley or oat stacks.

Straw is sold in London by the load of 11 cwt. 2 qr. 8 lb. or 36 trusses of 36 lb. each. In the provinces it is sold by the ton.

To ascertain the contents of Corn Stacks.—It is a very difficult matter to arrive at the quantity of grain and straw in an unthreshed stack by calculations based on measurement. The crops should, if possible, be valued standing.

The following table gives the comparative yields of grain and straw per acre :—

AVERAGE WEIGHT AND YIELD OF CROPS

Crop	Straw per acre			Grain per acre		
	Heavy	Medium	Light	Heavy	Medium	Light
	Cwt.	Cwt.	Cwt.	Bushels	Bushels	Bushels
Wheat	40	30	15–20	35–40	26–30	20
Barley	25	20	10–15	40–45	30–35	20–25
Oats	35	25	15–20	60–70	45–50	25–30

If measuring of the stack is resorted to, the dimensions should be taken in the manner directed for hay stacks and the following tables used, but the results are not to be depended upon.

Average weight of straw per bushel of grain.

Wheat = 112 lb.
Barley = 62 lb.
Oats = 61 lb.

Average weight of grain per bushel.

Wheat = 60 lb.
Barley = 47 lb.
Oats = 40 lb.

Number of cubic feet of unthreshed corn in stack to one bushel of grain.

Wheat = 24 to 27 cubic feet.
Barley = 20 to 23 ,,
Oats = 16 to 20 ,,

Example.—A stack of wheat measures 23 feet long, 12 feet wide, and 9 feet high. Find the number of bushels of grain, and the weight of straw.

$23 \times 12 \times 9 = 2484$ cubic feet. Putting it at 27 cubic feet to the bushel we get 92 *bushels of grain* in the stack. Taking the average weight of straw per bushel of grain as 112 lb. we get 92 cwt. or 4 *tons* 12 *cwt. of straw* in the stack.

When *grain is in the heap*, the number of bushels may be ascertained by taking four-fifths of the cubic contents in feet.

To ascertain the weight of roots in clamp.

Find the cubic contents of the clamp in feet and use one of the divisors given in the following table, according to the kind of root.

TABLE

Weight in pounds per cubic foot

Carrots	31
Parsnips	31
Turnips	33
Swedes	34
Mangolds	35
Potatoes	36

CHAPTER II

SURVEYING WITH THE CHAIN

By Land Surveying is understood the art of ascertaining and representing the shape, character, and area of any portion of the earth's surface, as projected on a horizontal surface.

Standard of Measurement.—Most surveyors in this country adopt the Gunter's chain, which is 100 links, or 22 yards, or 66 feet in length. Each link is, therefore, $\frac{1}{100}$ part of 66 feet, which is 7·92 inches. It was invented by the Rev. Edmund Gunter in the year 1620.

There is also another chain in use by surveyors which is 100 feet in length, and is used chiefly by builders and many engineers.

Advantages of Gunter's or the 100-link chain.—1. It is lighter than the 100 foot-chain.

2. In measuring to the nearest division there is less error than when using the 100-foot chain, because a link is shorter than a foot.

3. It is more suitable for the working out of areas, because (1 Gunter's chain)^2 = (66 feet)^2 = 4356 square feet = $\frac{1}{10}$ acre. Also 10 chains = 1 furlong, and 10 square chains = 1 acre.

Advantages of the 100-foot chain.—1. Being longer than the 100-link chain, it is more conducive to accuracy when measuring long lines.

2. It is more convenient where calculations are required to be made in feet, such as is the case in builder's work, town surveying, and in fixing road gradients. It is sometimes called the builder's chain.

3. It has an advantage in the lining out of curves based on the degree of curvature (though the 100-foot steel band is generally used for this work).

Land chains are made of the best cast steel wire or of iron, in different weights ranging from 4 to 9 lb., and costing from 7*s.* 6*d.* to 20*s.* The best chains should have welded and not open joints as they will then be less liable to stretch in use. In the Gunter's chain there is a brass tablet at 10 links from either end, at 20 links from either end the tablet has two teeth, at 30 links from either end three teeth, at 40 links from either end four teeth, and in the

centre at 50 links from either end there is a round piece of brass.

Care must be taken when reading the chain because the brass tablet which has two teeth may be either 20 links or 80 links, according as it is calculated from one end of the chain or the other.

Every chain has 10 arrows or pins about 15 inches long, and made of the best iron or steel wire. They are pointed at one end and have a ring at the other.

Besides the chains already mentioned there are the steel tape, steel band, 33-foot chain, and the 50-foot chain.

The steel tape is used when very accurate measurements are required: steel tapes can be had of any length required—cost, $\frac{3}{8}$ inch wide in case, 66 feet, about 18*s*.

The steel band chain is of great use for accurate chaining in small surveys, as it is practically unalterable in length, because it has no links which can become stretched or bent. It is stronger and more durable than the steel tape. The 33-foot chain and 50-foot chain are useful in measuring sloping ground and offsets to a chain line.

French Measures.—The decametre chain = 10 metres. The metre is nearly $\frac{1}{10000000}$ part of the distance from one of the earth's poles to the equator and equals 39·37 inches approximately. The 20-metre chain = 65·618 feet.

These chains are used in countries where the metric system obtains. It will be observed that the decametre chain is about half the length of, and the 20-metre chain (65·6 feet) very nearly the same length as, the Gunter's chain.

All areas of land, except in those cases where land is extremely valuable, should be expressed in acres, roods, and perches.

Example.—What is the area of a plot of land in the shape of a trapezoid, whose parallel sides are 15·21 chains and 12·42 chains respectively, with a perpendicular distance between them of 21·10 chains.

(See Chapter I, Mensuration Rules.)

15·21 }
12·42 } add

27·63 }
21·10 } multiply

5526000
276300
27630

2) 582·9930

291·4965 = area in square chains.

There are 10 square chains in one acre, therefore by moving the decimal point one place to the left we get 29·14965 acres.

To find the number of roods, multiply the decimal fraction by 4, thus—

$$\begin{array}{r} \cdot 14965 \\ 4 \\ \hline 0 \cdot 59860 \end{array}$$ and we get 0 roods.

To find the number of perches, multiply the decimal fraction by 40, thus—

$$\begin{array}{r} \cdot 59860 \\ 40 \\ \hline 23 \cdot 94400 \end{array}$$ and we get 23·9 perches.

∴ the area = (say) 29 acres 0 roods 24 perches.

To express roods and perches as the fraction of an acre, divide the number of perches by 160.

Example.

3 acres 2 roods 10 perches = 3 acres 90 poles.

$\frac{90}{160} = 0 \cdot 5625$ = 3·5625 acres.

Surveyors of experience know *at sight* how many roods and perches are represented by the decimal figures, and do not have to work them out by multiplying by 4 and 40, successively.

TABLE FOR CONVERTING DECIMAL PARTS OF AN ACRE INTO ROODS AND PERCHES

Perches	0 Rood	1 Rood	2 Roods	3 Roods	Perches	0 Rood	1 Rood	2 Roods	3 Roods
0	·000	·250	·500	·750	21	·131	·381	·631	·881
1	·006	·256	·506	·756	22	·137	·387	·637	·887
2	·012	·262	·512	·762	23	·144	·394	·644	·894
3	·019	·269	·519	·769	24	·150	·400	·650	·900
4	·025	·275	·525	·775	25	·156	·406	·656	·906
5	·031	·281	·531	·781	26	·162	·412	·662	·912
6	·037	·287	·537	·787	27	·169	·419	·669	·919
7	·044	·294	·544	·794	28	·175	·425	·675	·925
8	·050	·300	·550	·800	29	·181	·431	·681	·931
9	·056	·306	·556	·806	30	·187	·437	·687	·937
10	·062	·312	·562	·812	31	·194	·444	·694	·944
11	·069	·319	·569	·819	32	·200	·450	·700	·950
12	·075	·325	·575	·825	33	·206	·456	·706	·956
13	·081	·331	·581	·831	34	·212	·462	·712	·962
14	·087	·337	·587	·837	35	·219	·469	·719	·969
15	·094	·344	·594	·844	36	·225	·475	·725	·975
16	·100	·350	·600	·850	37	·231	·481	·731	·981
17	·106	·356	·606	·856	38	·237	·487	·737	·987
18	·112	·362	·612	·862	39	·244	·494	·744	·994
19	·119	·369	·619	·869	40	·250	·500	·750	1·000
20	·125	·375	·625	·875					

To convert links to feet.—Multiply by 66 and mark off the last two figures (i.e. divide by 100).

Example.—50 *links* = 50 × 66 = 33·00 *feet.*

To convert links to yards.—Multiply by 22 and mark off the last two figures.

Example.—50 *links* = 50 × 22 = 11·00 *yards.*

To convert feet to links.—Multiply by 100 and divide by 66.

Example.—33 *feet* = (33 × 100) ÷ 66 = 50 *links.*

To convert yards to links.—Multiply by 100 and divide by 22.

Example.—11 *yards* = (11 × 100) ÷ 22 = 50 *links.*

Customary and Statute Measure

Originally land measurement differed in various parts of England, being governed by custom: hence the term 'Customary Measure.'

At the present time land measurement all over England is governed by Acts of Parliament: hence the term 'Statute Measure.'

Three Acts are responsible for our present standards of measurement, viz.:—

34 *Henry VIII* (1542) enacted that the acre should be 10 square chains.

5 *George IV* (1824) enacted that the yard should be called the Imperial Standard yard. It is the distance between two marks on a certain bar which is kept in the Standards Office at Westminster. (There is a replica let into the raised pavement on the north side of Trafalgar Square.) It also fixed our lineal and square measures as given in Chapter I of this book.

5 & 6 *William IV.* (1835) abolished all *customary* weights and measures.

Occasions may occur, though very rarely, when it is necessary to reduce customary to statute measure. This may be accomplished as follows:—

Reduce the roods and perches to the decimal of an acre and multiply by the number of square feet or square yards in the customary acre. Reduce this quantity to acres, roods and perches by statute measure.

Example.—Reduce 10 acres 2 roods 20 perches customary to statute measure, when the customary acre contains 4000 square yards.

10 acres 2 roods 20 perches = $10\frac{100}{160}$ = 10·625 acres. 10·625 customary acres × 4000 (number of square yards in 1 customary acre) = 42500 (number of customary square yards). 42500 ÷ 4840 (number of square yards in 1 statute acre) = 8·781 nearly.

∴ 8·781 = the area in statute acres.

4

8·124

40

4·960

∴ The area in statute measure = (say) 8 *acres* 3 *roods* 5 *perches.*

Systematic Surveying.—With a thorough understanding of the ordinary rules of mensuration, there is no doubt that the survey of a piece of country could be made and laid down to scale on paper by anyone of average intelligence, provided that he took sufficient and careful measurements. Each field would be measured separately, and the trouble would begin when the surveyor wished to join the fields together on paper so as to make a complete plan. This would be bad enough, but it would be nothing to the difficulty which would confront the draughtsman who had never seen the country in question: he would be utterly at a loss to place them in their relative positions from the surveyor's field notes.

It is obvious then that a system is demanded, which will be understood by all surveyors.

Equipment.—First of all let us consider what equipment we shall require on setting out to make a complete chain survey of land. It should consist of a chain and arrows, already described, and the following:—

Ranging rods, poles, or pickets.—These are poles painted red, white, and black, of say 1 to 1½ inches in diameter, and from 10 to 15 feet in length, shod with iron so as the more easily to be inserted in the ground. The longer poles should have a white flag attached to the top so that they may be seen at a distance. These poles or rods are used for marking the station points and ends of the chain lines. Cost from 30*s.* to 60*s.* per dozen.

Pegs or **false pickets,** made of wood, about a foot long, pointed at one end and say 2 inches square at the other, for the purpose of marking stations. They should be driven into the ground to within 3 inches.

Offset Pole.—This is a rod of 10 links in length, each link being marked off in alternate bands of black or red and white: it is used for taking measurements from the chain line to inequalities in the boundaries: cost about 3*s.* 6*d.* A tape may be used for this purpose also, but it is not advisable, as it is liable to become permanently stretched with use, and so inaccurate. It is a nuisance when the ground is wet, and is quickly spoilt in such conditions.

A Field Book in which to enter measurements: a pencil and a piece of india-rubber. In addition to the above mentioned we might include a *Cross-staff* or an *optical square*, both of which will be described later, a bundle of laths or sticks called 'whites' for lining out the chain line if very long, a pair of field glasses, and three assistants.

Cadastral and Geodetic Surveys.—It might be mentioned here that the scope of this book does not extend beyond what is known as Cadastral Surveys. A **Cadastral Survey** is a field-by-field survey, made with the object of delineating correctly the boundaries of each field and showing its area and nature. The scale of such a survey, therefore, must be large enough to show clearly all detail; the 25-inch ($\frac{1}{2500}$) Ordnance Survey map may be taken as a good

example of a cadastral map. In cadastral surveys the spheroidal shape of the earth may be neglected, and its surface may be taken as a plane. We may, accordingly, solve all problems in this connection by plane trigonometry, and the error thus introduced will be a negligible quantity. The sides of the triangles in such surveys are taken as straight lines when they do not exceed six miles, but in longer lengths than six miles the curvature of the earth must be taken into consideration.

A Geodetic Survey, or trigonometrical survey, takes into consideration the shape of the earth, and spherical trigonometry must be used for the solution of the triangles laid down. That branch of surveying which deals with the survey of a country, or extensive areas of the earth, is termed *Geodesy*.

Method of Chaining.—The surveyor should take the chain when folded in his right hand, with both handles in his left hand, and throw it sharply from him, keeping hold of the two handles. If the chain has been properly done up, it will 'fly' clear, without any knots in it.

Poles are placed in the ground at the extremities of each line to be measured. Two men are required to 'run' a chain line, one to pull, called the 'leader,' and one at the other end to 'drive,' or give direction, called the 'follower.' The follower holds the handle against the first pole, and directs the leader, who takes the ten arrows, in line with the pole at the end of the chain line. At the end of this chain, and of each successive chain, the leader puts in an arrow, and the follower collects them as they proceed, until all the ten arrows have been picked up or the end of the line has been reached, when the follower gives them back to the leader. The leader should carefully count them, on receiving them from the follower, to see that one has not been left behind. This is called a *tally point*. Tally points should always be booked in the field book, whether an offset has been taken from that point or not.

To do up the chain after use, take hold of the round tablet at the centre, and double each pair of links backwards and forwards until the handles are reached; the chain when done up in this way should resemble a wheatsheaf: fasten with a leather strap. The arrows are best carried in a quiver, as they are dangerous things to have hanging loose, especially when getting over a fence.

Inaccuracies in Chaining.—Some of the many causes of inaccuracies arise as follows:—

1. Through not testing the chain before commencing a survey. In a large survey the chain should be tested daily. A steel tape is useful for this.

2. Through not pulling the chain tight when the arrow is put in by the leader.

3. Through the leader not putting in his arrow exactly perpendicular, and close to the handle of the chain.

4. Through the follower not keeping his arrow perpendicular when holding the handle of the chain against it.

5. Through not making allowance on sloping ground so as to reduce the measurement to the horizontal.

6. Through not taking sufficient care when traversing difficult ground, and going through fences.

7. Through not keeping in proper alignment.

When a long line has to be chained it will help the chainmen to keep in a straight line if intermediate points between the stations are ranged in at regular distances. For this purpose a bundle of laths is useful.

Whites, as they are called, may be cut for this purpose from underwood about 3 feet long. A piece of white paper inserted in a cleft at the top of the stick will enable it to be seen more easily.

8. Through a knot occurring in the chain, or a link becoming bent or kinked.

9. Through the follower losing an arrow.

10. Through reading the links at the end of a chain line, or booking them, wrongly.

11. Through variation of temperature from which the chain expands or contracts.

In this country, however, a variation of 80° F. (which more than covers the ordinary range of the temperature in winter and summer) makes a difference of about half an inch in a chain's length, which is practically negligible.

Chain Error.—The correct length of a chain on the ground is from the *outside* of one handle to the *outside* of the other. The chain should be held thus :—

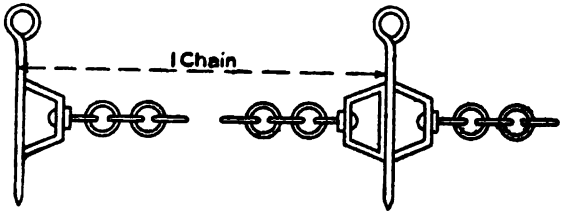


FIG. 1.

If both arrows are outside the handles the thickness of an arrow is added to the length of the chain. If one arrow is outside the handle and the other inside, then the thickness of a handle is lost.

If the chain is incorrect in length to start with, its error should be noted in the field book at the beginning and end of every day's work, and the mean taken as the correction required.

Correction of Chain Error.—When a line has been measured with an incorrect chain, the true length of the line may be found by proportion. The length of the correct chain is to the length of the chain used as the measured distance is to the true distance.

Example.—Suppose a chain has stretched 3 links and the measured distance is twenty chains.

Then 100 : 103 : : 2000 : true distance

∴ THE TRUE DISTANCE IS 20·60 CHAINS

The Surveyor's Field Book.—A surveyor's field book is used to record the sketches and measurements which have been made on the ground. It is of pocket form (i.e. opens from the end) and is usually about 8 inches long and 4½ inches wide. There are two methods of ruling the pages, one with two lines down the centre of the page lengthwise, forming a middle column, and one with one line.

The double line, or single line, represents the chain line, and

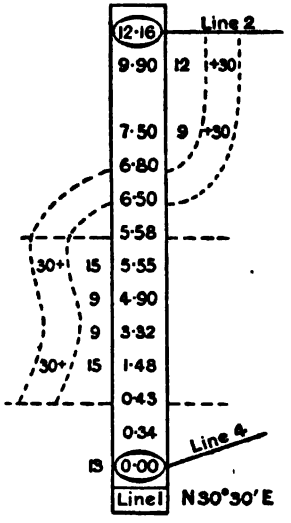


FIG. 2.—METHOD 1.
DOUBLE LINE.

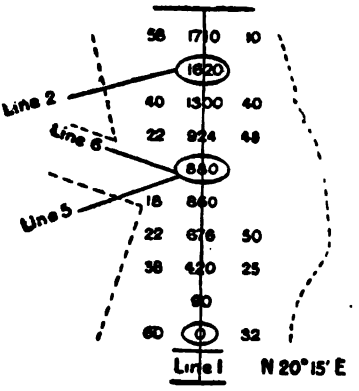


FIG. 3.—METHOD 2.
SINGLE LINE.

between them, or on it, are recorded all the measurements made on the ground which refer to the length of the chain. It is open to argument as to which is the better method, and it is probably only a matter of taste. With the double line all the chain measurements are kept to themselves, and there is little likelihood of their being mixed up with the offset measurements, which are placed alongside at right angles.

With the single line there is this advantage, that more room is allowed for sketching in fences and detail at the side, and when a fence crosses the chain line, it can be drawn across the single line, which may not be done when two lines are used. A reference to Figs. 2 and 3 will make this clear.

With reference to Figs. 2 and 3. The entry of the work should be done as follows:—

1. Open the book to what is usually known as the end, and commence at the bottom of the page, working upwards.

2. Draw a line across the first page about half-way, and underneath it write the name of the estate or farm, locality, and date.

3. Above the line draw a sketch of the survey lines (and fences if desired) you intend to 'run,' numbering them and showing the direction in which they are chained.

4. Starting with the first line, write at the bottom of the next page, within the chain column, or across if a single line, the words 'Line 1.'

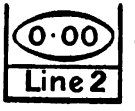
5. On the right of the words Line 1 enter the direction in which this line lies with regard to the north, i.e. its 'bearing.' (See use of Prismatic Compass.)

6. To commence with the readings of the chain. Enter in the column the first reading of the chain, which is 0·00, and put a ring round it thus (0·00). Only figures read from the chain, and no others, appear in this column. Wherever a station is reached a circle should be drawn round the figures in the chain column to indicate that it is a station. From this circle should be shown the approximate direction of other chain lines, with the number of each written against it.

7. Irregularities in boundaries, and all objects to be surveyed, are measured by means of offsets from the chain line. As the chain lies stretched tight along the ground, the point in it from which the offset is to be measured perpendicularly is noted in the chain column, and the length of the offset in links entered at the side outside the chain column.

8. Having reached the end of a line draw a single line over the last figures entered in the chain column.

9. At the right of the figures (0·00), in each successive line, is written the number of, and the distance in, the line from which that line starts, thus :



10. Proceed with all the survey lines, as described, until the survey is completed, and then draw a double line across the page.

Offsets.—Offsets are measurements from the chain line to the boundary : they are always made at right angles to the chain, and the right angle is generally judged by the eye when the offsets are short.

Offsets to buildings.—When offsetting to a building it is only necessary to fix two of the points by offsets as shown in Fig. 4. All important points should be fixed in this way, a single offset

being insufficient. A plan of the building should be drawn on a separate page, from actual measurements round the base.

A rectangular offset is one taken at right angles to the chain line, and an oblique one is taken at an oblique angle. In taking offsets with a tape, the ring of the tape is held at the spot to which

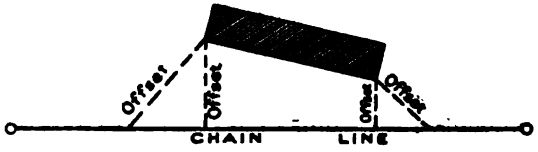


FIG. 4.

the offset is being taken, and the surveyor then swings the tape horizontally until the shortest measurement is obtained: this is the length of the offset, and also the point on the chain line at which it is made. Such an offset is called a *swing offset*. (See Fig. 5.)

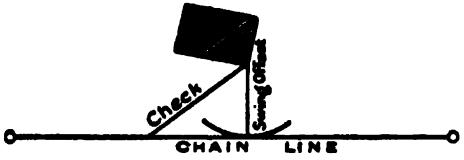


FIG. 5.

Secondary offsets may be used on certain occasions such as shown in Fig. 6. They are taken at right angles to the original offset.

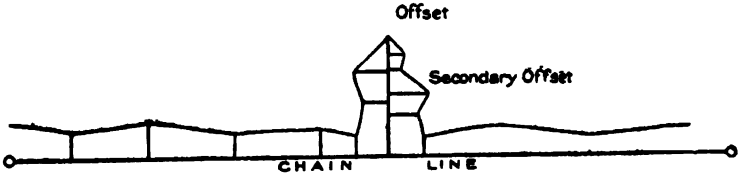


FIG. 6.

Where the work is important, it is better to erect a triangle as in Fig. 7.

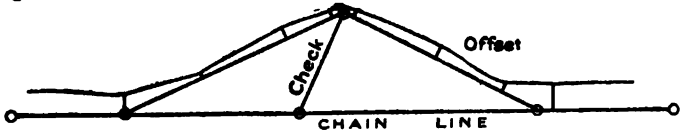


FIG. 7.

Length of Offsets.—Long offsets never give accurate results, and a limit of 100 links should be observed. Some surveyors do not consider that an ordinary offset, set out by the eye, should be longer than 50 links, and it is unquestionably safest not to exceed

this figure. If some instrument be used to set them out, such as the cross-staff, box sextant, or optical square, they may perhaps be as long as 2 chains. This would not matter in open country, but in towns, and where great accuracy is required, they must be kept short and taken as carefully as possible.

Offsets to a gate.—Fix one of the posts carefully by means of two offsets as shown in Fig. 4, and then measure the width of the gate. Or fix both posts with two offsets.

Offset to footset hedge.—A footset hedge is a hedge without a ditch which divides two properties. Take the offset to the centre of the hedge.

Offset to a hedge and ditch.—When plotting the boundaries of properties divided by a hedge and ditch, it should be remembered that the edge of the ditch farthest away from the hedge is the actual boundary, and not the hedge. (See Fig. 8.)

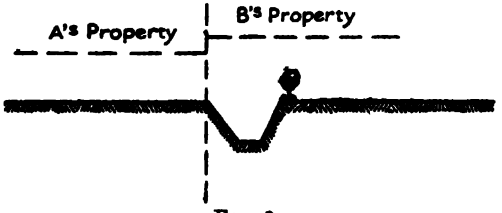


FIG. 8.

It is always advisable, however, to inquire in the neighbourhood the actual position of boundaries.

On a plan or estate map and in the field book, the side of the ditch on which the hedge stands may be shown conveniently with a small T. (See Fig. 9.)

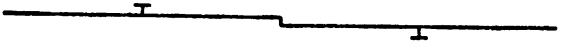
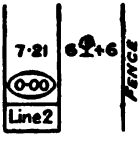
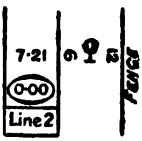


FIG. 9.

Offset to hedge with ditch on either side.—Take the offset to the centre of the hedge. When booking offsets to more than one spot, take each separately and place the sign + (*plus*) between them, thus :—



Or, in running measure, as it is called thus :—



In booking measurements of feet and inches, it is a good plan to do so as pence and shillings, thus :—4/3 instead of 4′ 3″.

How to set out a Line at Right Angles to another.—*Method* 1. *By the eye.*—This method should only be adopted for the purpose of obtaining offsets at right angles to the chain line. If the offset pole is laid on the ground with one end touching the chain and the

other pointing towards the object to be measured to, it can easily be seen if the two angles thus formed by the pole and the chain line appear equal. If they do not appear equal, move the offset pole either backwards or forwards along the chain until they do.

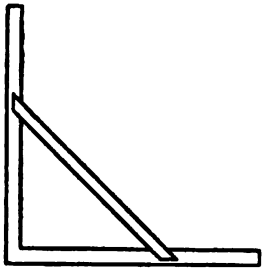


FIG. 10.

Method 2. *By means of a square* (Fig. 10).—This is a simple and fairly accurate method for setting out offsets, but it adds to the number of things to be carried about, which is a disadvantage. A square made of light deal with perpendicular sides of (say) 3 feet in length is laid on the ground with one side against the chain line.

Then—(*a*) If the perpendicular is to be erected from a given point in the chain line, the right angle of the square is placed at the point, and the perpendicular line sighted off.

(*b*) If from a given point *without* the chain line, the square must be held in the hand, keeping one side exactly over, and in line with the chain: the point in the chain where the perpendicular will fall may be fixed by walking either backwards or forwards until the given point is sighted along the edge of the square.

Method 3. *By means of a chain.*—There are two ways of doing this, either of which is suitable for ranging short lines, the given point being in the chain line.

(*a*) Let AB be the given chain line, and C the given point (Fig. 11). Measure off on the chain line from C a length CD equal

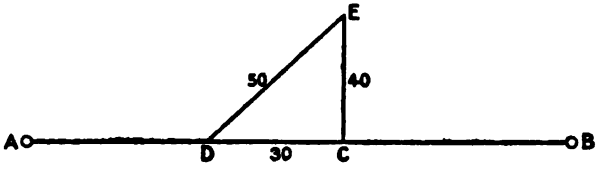


FIG. 11.

to 30 links. Place arrows in the ground at C and D. Fix one end of the chain at C and the ninetieth link at D. Take hold of the fortieth link and pull it out tight to E. The triangle thus formed will be a right-angled triangle (the angle DCE being a right angle), because DC = 30, CE = 40, and DE = 50, and by Euclid, I. 48, if the squares on two sides of a triangle together equal the square on the other side, the angle contained by the two former sides must be a right angle.

Example.

$$DC^2 + CE^2 = DE^2$$
$$\therefore\ 30^2 + 40^2 = 50^2$$
$$\therefore\ 900 + 1600 = 2500$$
$$\therefore\ 2500 = 2500$$

This method is very useful and often made use of in practice. The following whole numbers may also be employed : any multiples of these numbers will give right-angled triangles.

Sides of right-angled triangles :—

3	4	5
5	12	13
7	24	25
8	15	17
20	21	29

(*b*) Or again, let AB be the chain line and C the given point in it (Fig. 12).

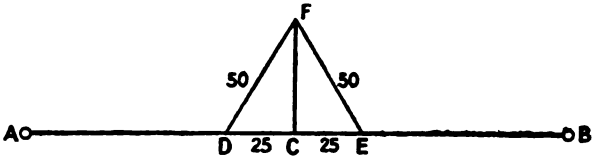


FIG. 12.

Measure off on each side of C a distance equal to 25 links to D and E. Fix one end of the chain at D and the other at E. Take hold of the fiftieth link, and pull it out tight to F.

Then CF *will be the perpendicular.*

Method 4. *By means of a cross-staff or cross-head.*—There are different forms of cross-staff (see Figs. 13 and 14), but a common

FIG. 13.

FIG. 14.

kind consists of a hollow brass box, octagonal in shape, and about 3 inches in diameter and 5 inches deep. (Cost about 7*s*. 6*d*.) It has slots cut in opposite faces of the octagon, one portion of the slot

containing a vertical wire. If the upper half of one slot contains the wire, the wire is placed in the lower half of the slot in the opposite face. There are consequently, pairs of slots at right angles to each other, and also pairs by which an angle of 45° may be laid out. The cross-staff has a socket which fits on to a pointed staff. The staff is placed in the ground so that a pair of slots corresponds to the direction of any line. A sight along another pair of slots gives the proper direction for an angle of 90° or 45° with the first line.

Fig. 15.

It is but a poor instrument and little reliance can be placed on it. It is only used, as a rule, in measuring land for ascertaining areas, when diagonals and perpendiculars are all that it is necessary to measure, as in Figs. 19 and 20 (p. 34). It has been superseded by the optical square.

A rough cross-head may be made out of a piece of round or square wood, 1½ inches thick and about 6 inches in diameter or sides, having two fine grooves ¼ inch deep in it which are at right angles to each other. This is fixed on the top of a pointed staff about

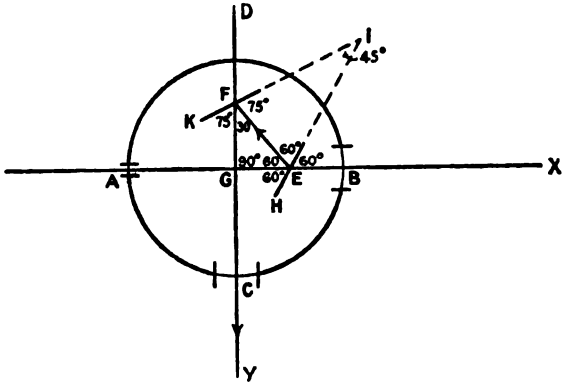


Fig. 16.

5 feet long so as to form a small table. It is used in the same way as described above.

Method 5. *By means of an optical square.*—This is a small circular metal box from 1½ to 2½ inches in diameter and ¾ inch deep, in which are fixed two mirrors inclined at an angle of 45° to each other. These are protected by a metal cover which slides round so as to cover the openings. (Cost about 30*s.*) (See Fig. 15.)

Fig. 16 is a plan of the instrument in section.

A is the eyehole, and B an aperture exactly opposite to A,

while C is the opening through which a pole at Y is reflected on to the mirror F. The mirror E is half plain glass and half silvered, and is inclined at an angle of 120° to the axis of the instrument, AB : the mirror F is all silvered and inclined to the axis AB at an angle of 165°. *To use* the instrument, look into the eyehole at A through the plain glass portion of the mirror E, and a pole at X is seen by direct vision. Let the eye now look on to the silvered portion of the same mirror E, and the line of sight is reflected at right angles to AX as shown by the arrow heads. An assistant with a pole at Y is moved backwards or forwards until the reflection of the pole Y is seen in the silvered half of the mirror E directly above the pole X as seen by direct vision. FY is then perpendicular to the line AX.

To find the point in the chain line which is at right angles to an object without, say Y, move backwards or forwards along the chain line until the object Y is reflected in the silvered portion of the mirror exactly above X. The instrument is then at the point in the chain required.

The theory of the instrument depends on the well-known law that a ray of light striking a plane mirror is reflected again from the surface at an angle equal to that of incidence, i.e. *the angle of incidence = the angle of reflection.*

Now the mirror E is placed at an angle of 60° with the line ABX, $\therefore$ AEH = 60°, and the mirror F is at an angle of 45° with the mirror E.

The angle of reflection AEH = the angle of incidence FEI

$\therefore$ FEI = 60°

also FEG = 60°

In the triangle IEF, IEF = 60° and EIF = 45°,

$\therefore$ IFE = 75°

But the angle of incidence KFG = the angle of reflection IFE = 75°—

$\therefore$ EFG = 30°.

In the triangle EFG, FEG = 60° and EFG = 30°,

$\therefore$ FGE = 90°.

So that the line FGY is at right angles to the line ABX.

The use of the instrument is practically confined to level ground, as if it has to be tilted in order to obtain reflection, the right angle is set off in an oblique plane, and is consequently not a right angle in a horizontal plane which is required.

The instrument is liable to get out of adjustment and should be tested occasionally. This can be done, in some instruments, by means of a screw or key which will slightly turn one of the mirrors.

To Adjust (Fig. 17). — Put in two poles at a good distance apart, and in exact line between these erect a tripod stand. Place the optical square upon the tripod. Put in pole 3 at a distance, so that it appears coincident by reflection with the direct sight of one of the two poles. Now turn the optical square right over, and sight in the opposite direction the other of the two poles and observe the third pole. If this still appears coincident by reflection, the instrument is in adjustment. If not, correct half the difference by means of the key provided for the purpose.

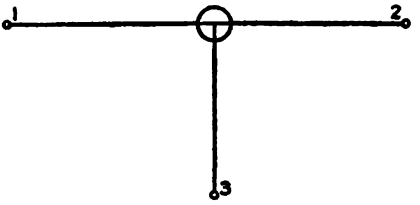


FIG. 17.

The optical square may be used on level ground for getting into line with two distant stations. Sight on to the first station and set out a perpendicular: then sight on to the second station and set out another perpendicular on the same side. Move to one side or the other until these two perpendiculars coincide. The position of the instrument will then be in line with the two stations.

HOW A SURVEY IS MADE

The area to be surveyed is laid out in a number of *triangles* which must be properly checked by subsidiary lines. The reason

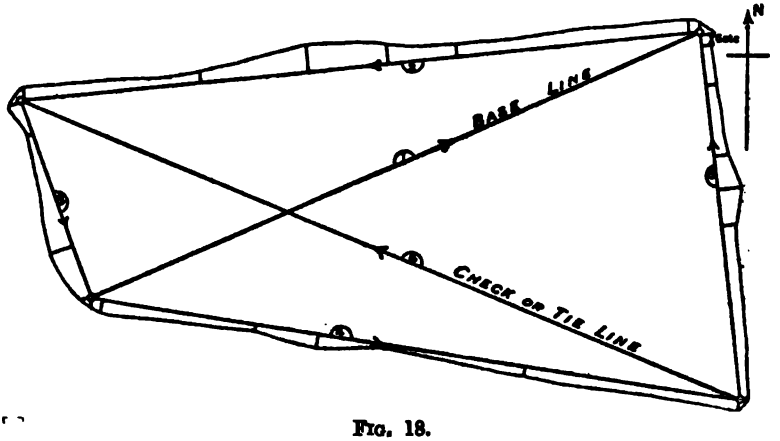


FIG. 18.

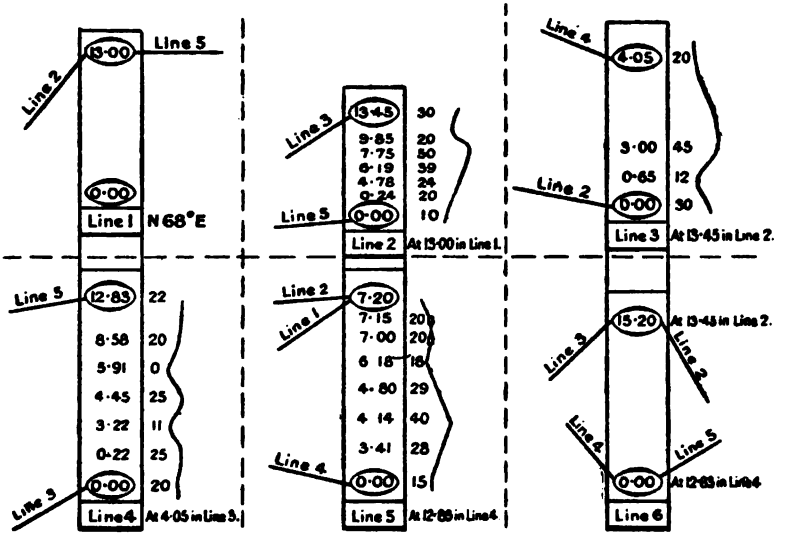
for adopting the figure of the triangle is because it is the only geometrical figure which cannot change its shape without at the

same time altering the length of its sides. Consequently, if we ascertain the length of its sides by measurement, its shape and size are determinate. *Proof* or *tie* lines must be run to check the work of measuring, which is, of course, liable to inaccuracy.

Small Surveys.—If the survey be of only one field it may be made by running a diagonal (see Fig. 18) and building on the diagonal triangles whose sides will run as near as possible to the boundaries. The triangles thus formed should be checked by a tie or check line.

The small circles represent the stations or poles. The chain lines are numbered, and the direction in which they are measured

Field Book of Fig. 18



is shown by the arrow-head. Offsets are taken from lines 2, 3, 4, and 5 to the boundaries at right angles to the chain lines, where shown. Line 6 is the 'tie' or 'proof' line which enables the figure to be checked when plotted on paper. The length of this tie line, as measured on the ground, should be the same as the distance scaled between the same stations on the paper (see chapter on Plotting), if the work has been done correctly. If the distances as measured and scaled are not identical and the error is a large one, the work must be done again. The purpose for which the plan is required will decide what degree of accuracy must be attained. An error of 1 in 1000 may be allowed: considerable care is necessary to obtain this degree of accuracy.

If a plan of the field shown in Fig. 18 were not required, but merely its approximate area, it would not be necessary to make

such a complete survey. It would be sufficient in this case to run a diagonal from A to B, leaving marks at the points on the diagonal at which the two perpendiculars upon it CD and EF

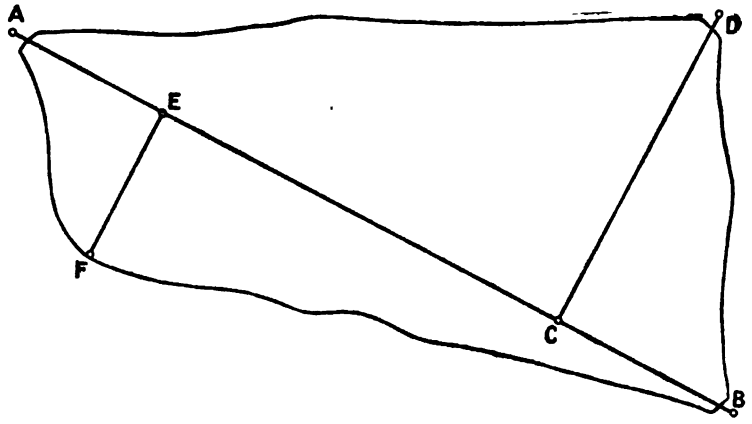


FIG. 19.

should be set off by means of a cross-staff or optical square. (See Fig. 19.)

The area could be calculated from these measurements according to the rules for triangles. (See Chapter I.)

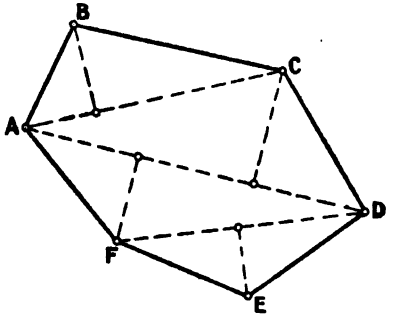


FIG. 20.

The lines AB and CD have been elongated a little so as to allow for the irregularities of the boundaries. If the boundaries were straighter, all the lines could be measured within the area, and a fairly accurate result would be obtained.

Fig. 20 gives another example of surveying when the area only is required.

The field book for Fig. 20 is as follows :—

Field Book

From ⊙F	749 366 0	208 ⊙E to ⊙D
F ⊙257 From ⊙D	1042 698 348 0	350 ⊙C to ⊙A
⊙B 270 From ⊙A	782 208 0	to ⊙C

When it is not possible to see the corners from one another or from any point within, it is necessary to set out three or more poles within the field at convenient places and chain the distance from them to the corners. In this manner the field is triangulated, and the perpendiculars are measured within the different sets of triangles as before described.

This is the easiest and quickest method of surveying when only the area is required.

Surveys larger than One Field.—In the case of a survey of (say) 20 to 50 acres, the first thing to be done, before laying down any survey lines, is to make a reconnaissance, and rough sketch-map. By walking over the ground it is possible to see the lie of the land, so that the best places for the main stations can be selected and the best way to lay out the chain lines chosen. The various difficulties and obstacles are noted and a rough sketch of the area to be surveyed is drawn in the field book. The sketch also contains the chain lines and stations adopted for the survey.

In laying down the survey lines the whole area should be divided as nearly as possible into two equal portions by a line called the *base line*. This line should be the longest line it is possible to get conveniently within the area to be surveyed : it should be selected over as level and open ground as possible and should be measured twice or three times to ensure the greatest possible accuracy. On it the other lines in the survey are based in the form of triangles, their stations being so selected that they will be clearly visible from each other, and will give a clear straight line for measurement between them.

FIG. 21.

By selecting a base line in the centre of the survey accumulation of errors in the system of triangles laid out on it to take in the boundaries is avoided, because the liability to inaccuracy in the triangulation increases with the distance from the original base. Additional lines must be run inside the triangle wherever a fence has to be picked up and offsets are taken, as required, from them to the fence. Every triangle must be properly checked. Very often a line crossing in the form of the letter X will check the whole survey as shown in Fig. 18. This is a good form of check to adopt where possible.

Generally, however, the lines required to pick up the fences will check the triangles without the addition of extra lines. A careful study of Fig. 21 and its field book (pp. 38, 39) should make the work quite clear.

Larger Surveys.—In large surveys there will be a system of base lines, more triangles, and more chain lines, and much more detail to take up; but the same principles apply, and the following points should always be observed:—

1. The triangles should be disposed so as to suit the ground to the best advantage. They should be as large and as few as possible; the longer the chain lines the better.

2. The sides of the larger triangles should run as close as possible to the boundaries, so as to avoid long offsets, or the necessity of making subsidiary triangles to pick up the boundaries.

3. The triangles formed should be well-conditioned; *i.e.* the angles should be neither too acute nor too obtuse. Angles of less than 30° or more than 150° should be avoided.

4. The lines inside the main triangles should terminate where possible in the base line.

5. It is permissible to make a short production of a long fixed line, but not a long production of a short one. The end of the line, so produced, should be fixed by a tie line, if important.

6. Always work from whole to part, and not from part to whole.

7. Always check every triangle or important point, such as a long offset, by one or more independent measurements.

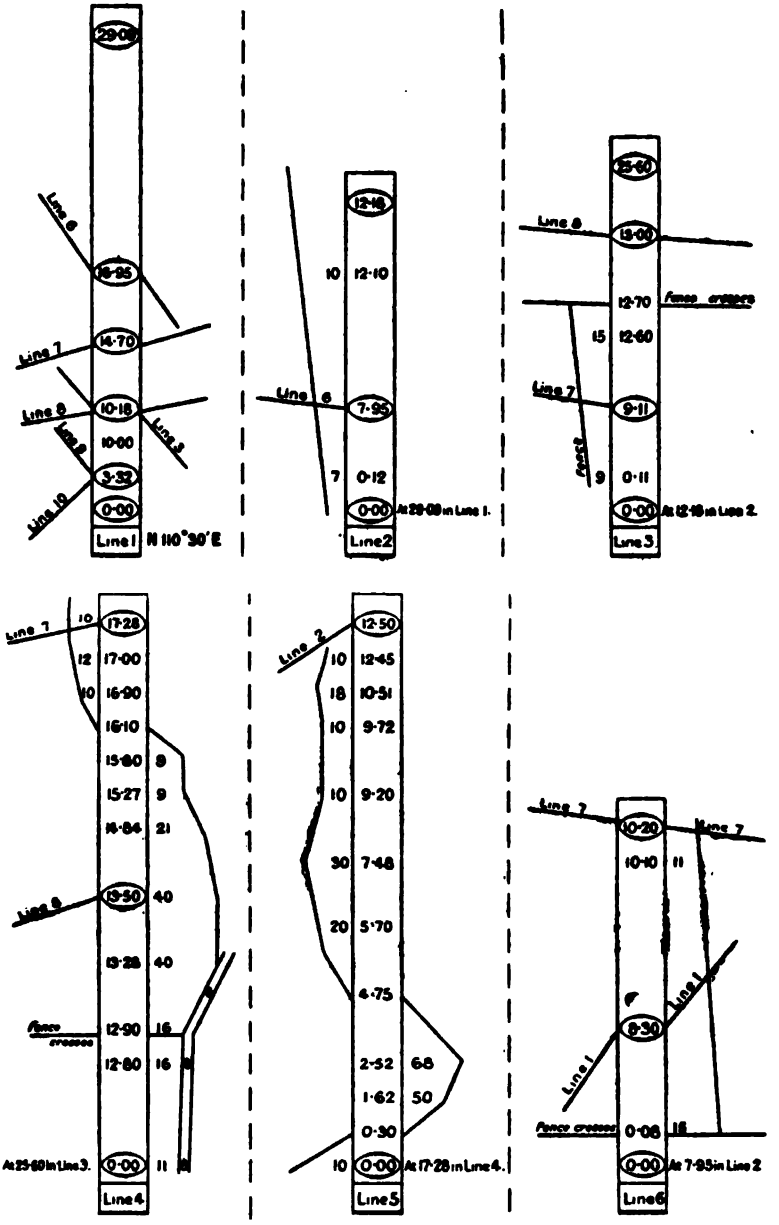
Extent of Use of Chain Surveys.—In an open country which is not very hilly there is nothing more accurate than a chain survey for preparing plans on a large scale, but it is advisable to limit its extent to about 600 acres. In a hilly country it is not so accurate, besides being very laborious: in such cases instrumental surveying should be adopted.

The Prismatic Compass.—Natural magnets being very rare, artificially magnetised pieces of steel are used instead. The usual process of magnetising a bar consists in rubbing it with an already magnetised bar.

The magnetic needles of surveying instruments are usually made in the form of flat bars with a cap at the centre which is balanced on a fine point.

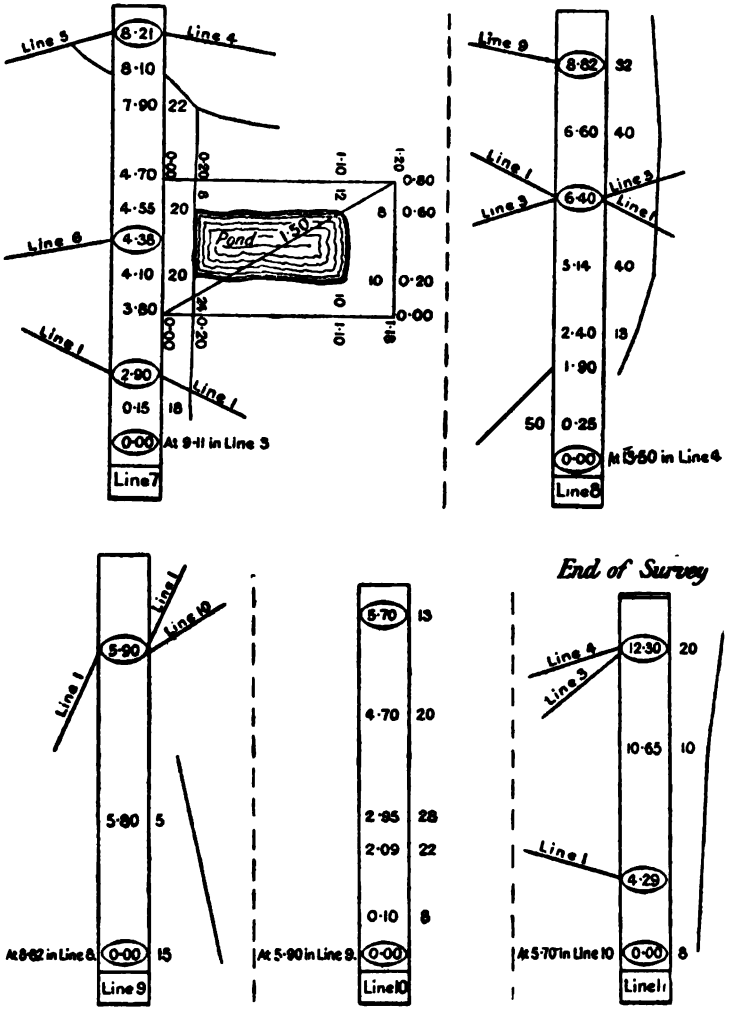
In some cases the longest section is placed horizontally and in

Field Book of Fig. 21



others vertically. If horizontally the needle is called a 'broad needle,' and if vertically an 'edge-bar needle.' The latter, of course,

Field Book of Fig. 21—*cont.*



is required when it is necessary to read a fixed scale of divisions because it can be ground to a sharp edge.

The 'cap' at the centre is generally made of some hard precious stone, mounted in a brass cup. The stone generally used is an agate. The needle is balanced on a hardened steel point. On

account of the steel point, upon which the needle swings, being liable to wear, and so prevent freedom of movement, all surveying instruments are fitted with a means of lifting the needle off its point.

In order that the survey may be laid down on paper, or plotted, so that it is possible to determine its position with regard to the points of the compass, it is necessary to take the direction of the first line of the survey by a compass. The instrument used for this purpose is the prismatic compass. Fig. 22 shows a type of instrument made by Messrs. Thornton, Manchester.

Its Use.—To obtain the direction in which the first line lies proceed in the following manner. Stand at the end of the line with the prismatic compass, holding it exactly over the first station (or if it is mounted on a tripod, which is better, set the latter up exactly over the station); look through the slit on the top of the prism P, align the sight-vane S on to the end station, and when the needle steadies read the number of degrees from the card. This can be done by means of the reflecting prism at the same time as the sight-vane is observed on the end station, without moving the eye from the slit. Care should be taken to hold the instrument in a horizontal plane so that the needle may swing freely.

FIG. 22.

R is a mirror which is supplied with the instrument. It slides on and off the sight-vane S, and is for the purpose of reflecting the images of objects above or below the horizontal plane of the observer's eye. If the magnetic azimuth of the sun be required the dark glasses N must be interposed between the sun's image and the eye.

When not in use the sight-vane, which is hinged, is shut down on the glass and the prism turned down, so that the instrument can be packed into a leather case. (Cost about two guineas.)

The direction of the first line of the survey as obtained by the prismatic compass is called its 'bearing,' and the angle read is *always* so many degrees *East of North*. The bearing of a line, then, is the angle it makes with the magnetic meridian, and is measured from the meridian to the line in the direction of the hands of a clock. Meridian may be defined as 'a great circle supposed to be drawn so as to pass through the poles of the earth, and the zenith and nadir of any given place intersecting the equator at right angles.' The *azimuth* of a straight line is the angle which it makes with the great circle of the meridian passing through a point in the same; or, in plainer language, is an angle taken *horizontally* with the

meridian as opposed to an angle in elevation. It will be understood, from what has been written, that the prismatic compass gives 'bearings' and not 'angles.' The horizontal angles between any distant objects are obtained by taking the difference of their observed bearings.

To test the accuracy of a Prismatic Compass.—Stand on a straight line and observe the bearings of this line in both directions: these should be the opposite points of the compass. Repeat the experiment on another straight line nearly at right angles to the first. This will test the card as to accurate centring.

It is not necessary to have a Prismatic Compass to obtain the bearing of the first line of a survey, though it is the proper instrument for the purpose; it may be taken with an ordinary compass thus: Hold the compass exactly over the station, wait until the needle steadies and points to the magnetic north, then read the number of degrees contained by the angle formed by the needle and the survey line. It is as well to take this reading from either end of the chain line as a check. Note in the field book whether the bearing is east or west of north in this case.

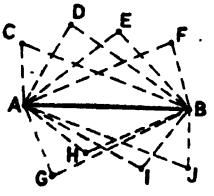


FIG. 22A.

Surveying with the Prismatic Compass.—There are two methods, one is known as *Traversing*, to be described later, and the other as the *Triangulation* method.

Measure a base line in the centre of the area so that the majority of important points around may be visible from the ends of it. Take bearings from the *two ends* of the base line to all the objects required, and check bearings from each of these objects on to the ends of the base line, and on to one another.

Bearings taken from both ends of a line should differ by 180°. The positions of objects are thus fixed by the intersection of lines drawn from the points of observation. Any two of the extreme points of the first survey thus fixed will act as a fresh base for extending the survey in a similar manner in other directions. A large area of country can thus be surveyed in pieces, but the accuracy of the work will only be approximate unless checked by fitting in with the known points of some trigonometrical survey. Fig. 22A shows the base line AB of a prismatic compass survey, with the points C, D, E, F, &c., fixed by intersection from either end.

Magnetic Variation.—The compass needle does not point to the true north, i.e. to the North Pole. Its direction is continually and regularly varying, the needle at present (1914) at Greenwich pointing about 15° 10′ to the west of the north. It will continue to change annually, approaching nearer to the north at the rate of about seven to nine minutes per annum, and then it will continue to change in the same direction for some distance to the east of north.

Afterwards it will swing back again, the maximum east or west of north being about 25°. The number of degrees given by the compass is the number of degrees which we enter in the field book, the allowance for variation being made only when the work is plotted. In plans of land we generally show the direction of the magnetic needle with the north point as in Fig. 23.

This deviation of the needle is called the '*Declination of the Needle.*' It varies at the same place yearly, at different times of the year, and to a smaller extent diurnally. The diurnal variation is said to change continually at the rate of one or two minutes per hour, being greater in summer than in winter.

A chart is published which gives the declination of the needle at different points of the earth's surface, and lines drawn through those points at which the variation is the same are called '*Isogonic Lines.*' The line along which there is no variation is called the '*Agonic Line.*'

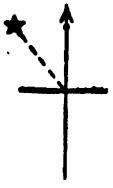


FIG. 23.

The arrow represents the magnetic north and the star the true north.

Besides this variation the needle is subject to violent and irregular disturbances which are known as magnetic storms. The needle in these circumstances oscillates rapidly. Earthquakes, volcanic eruptions, and an Aurora Borealis will cause these occasional vibrations.

Local attractions, such as iron pipes in the ground, lamp posts, railings, even steel about the person, may cause trouble.

It will, consequently, be seen that the compass is not an instrument of precision, and a survey conducted with it can probably not be relied upon to a greater degree of accuracy than $\frac{1}{2}°$. It is, however, a very useful instrument for rapid work and for filling in the details of a survey, especially when there are several points on which the work may be checked. So far we have considered only magnetic needles which are set free to move in a horizontal plane, but, though it does not concern our work with the prismatic compass, it is worth while noting that if needles were so supported as only to move in a vertical plane, it would be found that they would 'dip' down from the horizontal.

The 'dip' varies, just as the declination, at different places, and lines connecting those places where the 'dip' of the needle is the same are called '*Isoclinic lines.*' The line along which there is no dip is called the '*Aclinic Line.*' At the magnetic poles a dipping needle stands vertical.

As the declination of the needle is different at different places and different times, it is therefore absolutely necessary that a surveyor who uses a compass should be able to determine its variation on the spot by astronomical observation.

To find direction of True North.—1. In our hemisphere the shortest shadow of the sun on any day points to the true north.

2. A north and south line may be found approximately by

pointing the hour hand towards the sun and bisecting the angle made between it and the XII on the dial.

3. Obtain the magnetic north by the prismatic compass and find its variation by reference to Whitaker's Almanac, under the heading 'Magnetic Elements.'

4. Select a convenient piece of ground, which is level, and erect a pole (this might be done on the base line) perpendicularly. About an hour or so before mid-day make a mark on the ground at the extreme end of the shadow and put in a peg. Now, with the bottom of the pole as centre, and the distance from it to the peg as radius describe the arc of a circle upon the ground in the same direction in which the shadow will move. After mid-day, when the sun is sinking, watch carefully until the end of the shadow again coincides with a point in the arc described, and put in a second peg. Bisect the distance between these pegs and put in a third peg. A line ranged through the bottom of the pole and

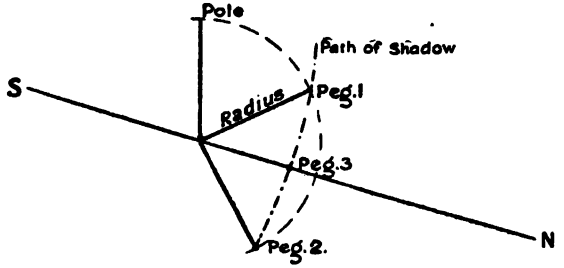


FIG. 24.

the peg marking the bisection will be in the direction of true north. (See Fig. 24.)

Nos. 3 and 4 are sufficiently accurate for ordinary chain surveys, but in the case of some important trigonometrical survey an astronomical observation would be necessary, as follows :—

5. Take the bearings of the sun at sunrise and sunset, when its lower limb (i.e. the lower edge of its circle) is a semidiameter above the horizon. Bisect the angle formed and this will be the direction of the true meridian.

6. Observe a star an hour or so before it crosses the meridian (the time of this can be ascertained from the 'Nautical Almanac'), and note on the theodolite the horizontal and vertical angles. When the star is observed again at the same altitude after passing the meridian read the horizontal angle. If the horizontal angle between the first and second observations of the star be bisected, the direction of the true meridian is obtained.

Nos. 5 and 6 require a knowledge of the use of the theodolite, which is explained later in the chapter on Theodolite Surveying.

Surveying past Obstacles

To continue a chain line which would pass through a building

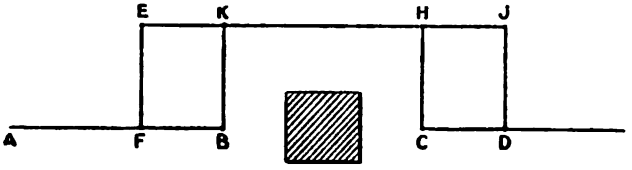


Fig. 25.

(Fig. 25).—Let ABCD be the chain line, the building being as shown. It is required to find the distance BC and to continue the chain line CD in a straight line with AB.

Take any point F in AB. Erect perpendiculars FE and BK. The lengths of the perpendiculars must be sufficient to clear the building and be equal. The lengths of FB and CD should never be less than three times that of the perpendiculars FE and CH. Now put in poles at E and K and continue the chain line from E through K. When the building is passed put in poles at H and J and erect perpendiculars similar in all respects to those at F and B. Put in poles at C and D. The chain line may now be continued from C and will be in a straight line with AB. The distance from B to C is equal to the distance measured from K to H.

To continue a chain line across a pond (Fig. 26).—Let ABCD be

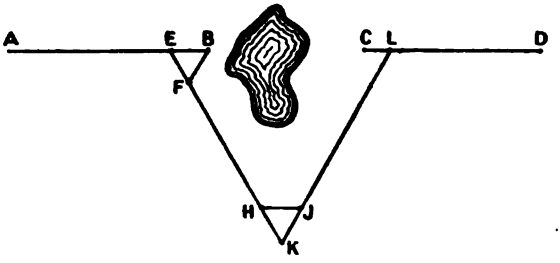


Fig. 26.

the chain line, the pond intervening as shown. Set up poles at B and C. Measure back from B towards A a distance BE equal to 50 links. Fix one end of the chain at B and the other at E. Now take hold of the fiftieth link and pull it out taut to F. EBF is then an equilateral triangle. Put in poles at E and F and chain a line from E through F to K until the point K is rather more than midway between B and C. Now make another equilateral triangle on EK —namely, HKJ—as before described. Put in poles at K and J and chain a line from K through J to L, making KL equal to EK. Then EL equals EK or KL.

A check upon the work is obtained by sighting B, C, and L in the same straight line.

Or, if an octagonal cross-staff be used, as follows (Fig. 27) :—
Set off the angle DBC = 45° and BCD = 90°.

Then $BD = \sqrt{BC^2 + CD^2}$

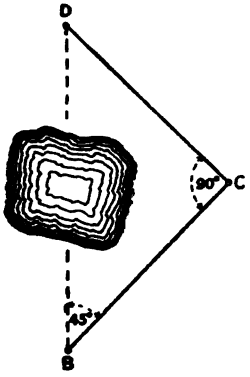


Fig. 27.

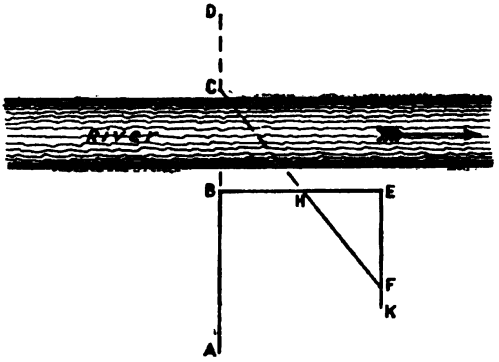


Fig. 28.

To continue a chain line across a river (Fig. 28).—Let ABCD be the chain line, the river intervening as shown. When near to the bank of the river erect a perpendicular to the chain line BE, say one chain long. Bisect BE at H and place a pole in at H. At E erect another perpendicular EK and find a point F in EK, by moving along the perpendicular, which sighted through H will be in line with a pole C on the opposite bank.

Then BC = EF

The width of the river is found by adding together the distances from B and C respectively to the river's edge, and subtracting their sum from BC.

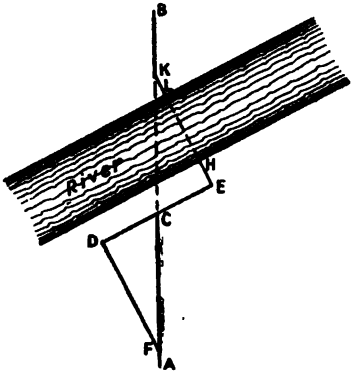


Fig. 29.

Or, when the chain line crosses the river in oblique direction (Fig. 29).—Let AB be the chain line, the river intervening as shown.

Lay out a line parallel to the river's edge, and measure off on it equal distances on either side of the chain line, say 1 chain from

C to D and C to E. At D and E erect the perpendiculars DF and EH. Put in a pole at K, on the chain line, in line with EH.

Then EK = DF.

DF may be measured on the ground.

In the methods described the optical square should be used for setting out the right angles; if the surveyor has neither optical square nor cross-staff he must adopt method No. 3, explained under the heading—*How to set out a line at right angles to another.*

The results obtained when chain angles are used are not altogether satisfactory, and there is no question but that it is better to use either the box sextant or theodolite for measuring the angles, and then to calculate the result by trigonometry. The use of these instruments is described in a later chapter.

Surveying Hilly Ground.—Two difficulties present themselves when chaining lines over hilly ground:—

1. The poles being obstructed from sight.
2. The actual measuring of the lines so as to arrive at the horizontal.

Ranging Lines.—When the country is very undulating poles will have to be set up at very short distances. The line should be ranged with three poles at a time; that is to say, when the distant pole cannot be seen from a point in the line, the next pole in the line must on no account be put in without having three of those previously set up in sight. When the line has been properly ranged with poles the latter may be removed and whites substituted. This saves carrying a great number of poles.

There are many obstacles to impede the surveyor in chaining his lines such as hedges, woods, bushes, rivers, and buildings. The method of overcoming the difficulties presented by rivers, buildings, and similar obstructions has been shown, and in the case of hedges, bushes, and woods, when the work is important, recourse must be had to a bill-hook to clear a gap sufficiently large to make the line visible on the opposite side: usually a clear cut is necessary from ground to daylight above so that the line is always in sight whether the ground falls or rises.

Ranging through a valley.—The poles EC and DF have their

FIG. 30.

positions fixed by sighting through from A and B, and intermediate whites may be ranged in, as explained before, at (say) every four chains.

Ranging over a hill.—When it is impossible, through a hill intervening, to see from the first to the last station of a line, the intermediate point may be found as follows :—

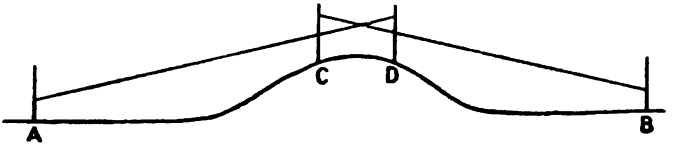


FIG. 31.

Let A and B represent the first and last stations on the line; it being impossible to see from one to the other (Fig. 31).

Let two men stand on the rise of the ground with poles at C and D. Each man is, as near as can be judged, in alignment with A and B, but in such a position that the man at C can just see the pole at B, and similarly the man at D can just see A.

Let D sight C in line with A and C sight D in line with B; by manipulation D will in time sight C in line with A at the same time as C sights D in line with B. Whites can be ranged in if the line is long, as already described.

If the stations A and B are both visible (as in sketch below) from some one position in the line on the hill, it is possible to determine the exact position of the spot by means of the cross-staff.

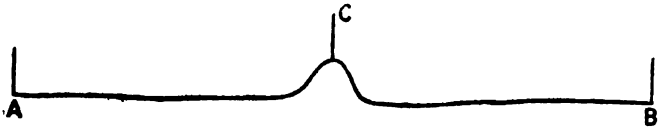


FIG. 32.

Ranging a long hill.—When from no point upon the hill can the poles A and B both be seen, it is necessary to set out a false line, by the use of several poles, from the station A, proceeding in the direction of station B as nearly as may be judged.

Next it is necessary to find out the length of the false line and its final error with regard to B. From this it will be possible to calculate how much any point on the line should be moved either to the right or the left.

Example.—Let the false line measure 15 chains and the error at the end of the line, B, 15 feet to the left. Then a pole at one chain from A must be moved 1 foot to the left, a pole at 2 chains from A must be moved 2 feet to the left, a pole at 3 chains 3 feet, and so forth.

The Line Ranger.—This instrument consists of two right-angled prisms of glass or mirrors E and F placed one vertically above the other in a small box like the optical square, so that their reflecting planes HI and LK are at right angles to one another.

Fig. 33 (p. 48) shows the instrument in plan. There are slits at P and O, and openings at M and N.

To use the instrument, hold it so that the eye is at P, then on looking into the top mirror the pole at B is reflected, and on looking into the bottom mirror (if the instrument is in the direct line AB)

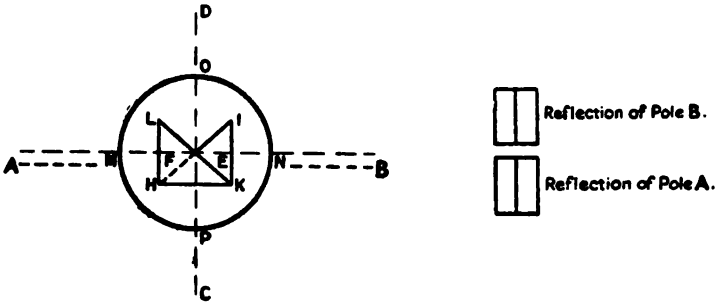


FIG. 33.

the pole A is reflected. Therefore, by holding the instrument in front and walking backwards or forwards in the line CD until the pole B is reflected above the pole A, so as to make one straight line with it, the position of an intermediate point is found. The instrument can only be used on level ground.

Chaining on Slopes.—The second difficulty to be overcome when surveying hilly ground is that of chaining so that all distances may be measured horizontally, as the survey must be projected horizontally on paper.

To measure along the slope gives a greater length than that which should be plotted. It may be observed here that no more houses could be built on the slope than on the horizontal length; though if the ground were purchased at so much per foot hypotenusal measurement, more would be paid for it than if measured on the horizontal. A glance at Fig. 34 shows this clearly: its horizontal measurement is 4 chains and its hypotenusal 4·50 chains. A deduction therefore must be made from the measurement on the slope to reduce it to the horizontal distance. There are two ways in which we can arrive at the required measurement.

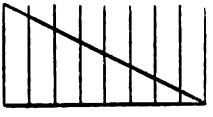


FIG. 34.

Method 1.—*By chaining down* the hill in the ordinary way and reading the angle of slope with some angular instrument such as the Abney level or clinometer and making allowance for the difference between the sloping and the horizontal measurements, as given in the following table of links to be subtracted from each chain.

Table for reducing Measurements on Slope to Horizontal
(*66-foot chain*)

Degrees	Links	Degrees	Links	Degrees	Links	Degrees	Links
5	0·4	14	3·0	23	7·9	32	15·2
6	0·6	15	3·4	24	8·6	33	16·1
7	0·7	16	3·9	25	9·4	34	17·1
8	1·0	17	4·4	26	10·1	35	18·1
9	1·2	18	4·9	27	10·9	36	19·1
10	1·5	19	5·4	28	11·7	37	20·1
11	1·8	20	6·0	29	12·5	38	21·2
12	2·2	21	6·6	30	13·4	39	22·3
13	2·6	22	7·3	31	14·3	40	23·4

The rule for applying the corrections, in the tables to the measured distance on slopes is: *Multiply the correction for one chain by the number of chains and subtract from the measured distance.*

Example.—Distance measured on a hill which slopes at an angle of 7° = 12·07 chains, i.e. 12 chains 7 links. The correction for 7° is 0·7 links per chain.

∴ Horizontal distance = 12·07 × 0·7 = 8·449 links.
12·07 chains − 8 links = 11·99 chains.

When the ground has several different slopes it is necessary to measure and reduce each separately.

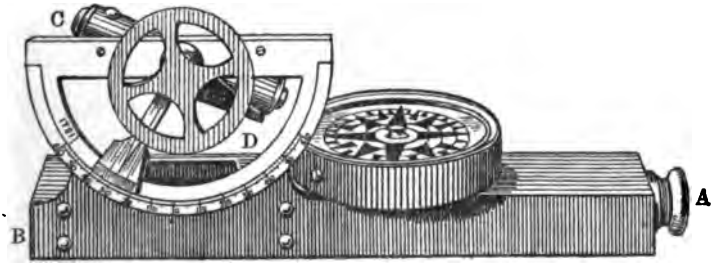


Fig. 35.
(*From Lupton's 'Mine Surveying.'*)

The *Abney Level* is shown in Fig. 35. This little instrument is about 5 × 2½". It has a pin-hole sight at A and the other end of the tube B is half-closed and has a wire across it. A sight is taken by looking through A and across the hair at B. C is a small bubble-tube. The casing underneath the bubble-tube, and

of the tube at D, is cut away so that the bubble may be visible from the interior of the tube by means of a reflector. When the bubble is in the centre of its run it is seen to be bisected by the wire. On directing the wire at B to the object the milled-edged wheel is turned until the bubble is bisected by it. The angle is then read from the arc. The method of reading the vernier scale is explained in the chapter on Scales. (Cost about £2.)

To use it place a pole at the bottom of the incline marked with a piece of paper at the height of the eye of the observer. The observer then standing at the top of the incline sights the mark on the pole at the bottom of the incline, and reads the angle from the arc on the instrument. It is as well to read the angle from both poles, as a check.

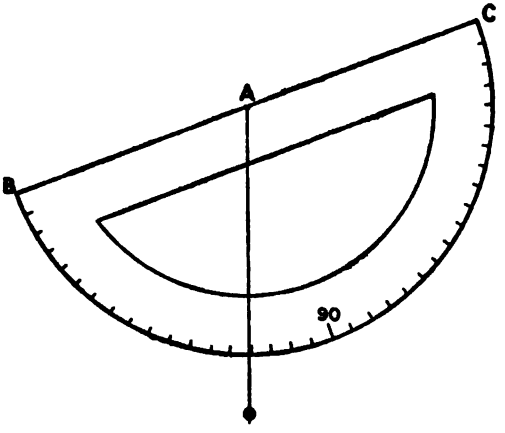


FIG. 36.

A rough and fairly accurate method of obtaining an angle of slope when without a proper angular instrument is to use an ordinary protractor as shown in Fig. 36 with a small notch filed in it at A.

Hang a small weight by means of a fine cotton over the protractor at the notch A. Place poles at the top and bottom of the incline marked at the same height above the ground, say 5 feet, standing at the top of the incline and holding the protractor at the mark sight along the straight edge CB to the mark on the pole at the bottom, allowing the weight to hang freely. As soon as the weight is steady, clip the cotton on to the protractor with the fingers, and read the number of the degrees of the angle between the cotton and the ninetieth mark on the protractor.

It will be seen from the table of allowances for slopes that, at an angle of 4°, which is a considerable incline, only about ¼ link per chain is to be deducted. Many surveyors, consequently neglect to make allowance in ordinary field surveys for small slopes'

Nevertheless, where great accuracy is required the allowance should always be made, and it is important always to make the reductions to horizontal measurement on the field. An altered field book causes doubt as to its accuracy.

Fig. 37 shows the Clinometer Rule. This clinometer is made like a folding rule, but is shorter and stouter. Each arm carries a

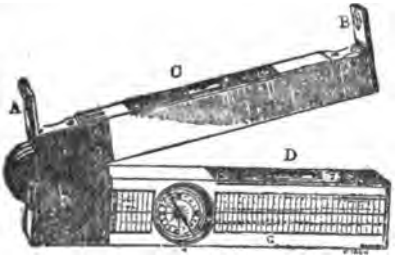


FIG. 37.

FIG. 38.

bubble tube (C and D), the top arm being fitted with a sight A and cross wires B at the ends.

By laying a rod on the ground and placing the clinometer rule on it, the angle of inclination may be found by raising the top arm on its hinge until the bubble is in the centre of its run. The number

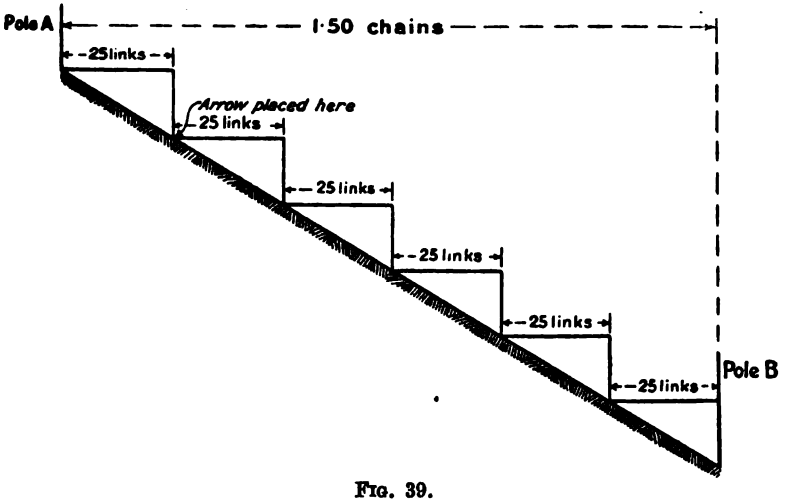


FIG. 39.

of degrees is read from the hinge F of the rule. (Cost about 35*s*.) There are several varieties of this instrument.

Method 2.—*By stepping* with the chain. This consists of measuring the slope in half-chain or, preferably, quarter-chain (25 links) lengths, and holding the chain horizontally. At the end of each short length an arrow is put in immediately underneath. An

arrow called a drop arrow (Fig. 38) is made for the purpose, with a weight of lead attached so that it will fall perpendicularly, but it is an unnecessary addition to carry about : a plumb bob or even a ranging rod held at the end will serve the purpose. It would be impossible to pull the chain out horizontally to its full length as there would be a sag in the middle, so that the shorter the lengths used the less liability to error from sag. A glance at Fig. 39, p. 51, will make this method quite clear.

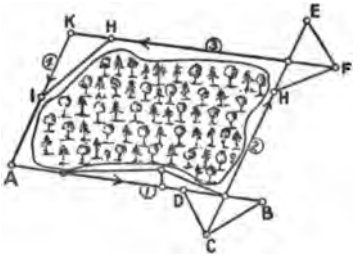


Fig. 40.

Survey of a Wood or Pond.— When it is not possible to run a diagonal, as in the case of woods or ponds, it is necessary to chain round the figure and to fix the relative directions of the lines by means of what are known as *chain angles*.

Fig. 40 shows the lines that are required to be run in order to make a survey of the wood. Line 1 is tied to line 2 by the tie BC and checked by DC so that the direction of CE is fixed. Line 3 is tied and checked similarly by EF and HF, and line 4 by HI. When plotting the work on paper the length of line 4 as measured on the ground should fit in between the stations K and A as scaled.

Traversing by the chain only in this fashion is not at all to be recommended. In order to produce good work the greatest care to secure good ties at the junctions of the lines is necessary. Such ties should be long lines, if only short ones can be obtained the work cannot be depended upon.

Instrumental work has taken the place of such surveys, and the subject is dealt with in the chapter on Traverse Surveys.

CHAPTER III

SCALES

THE term **scale** is used to express the proportion which a plan bears to the object which it represents. The *Scale of a Map* is the proportion which the distance between any two points on it bears to the distance between the same two points on the ground. We generally express this proportion in words with reference to the inch., e.g. 1 inch to the chain, 2 inches to the chain, 1 inch to the mile, 6 inches to the mile, &c.

The scales of foreign maps generally bear the proportion of 1 to some multiple of 10, and are expressed by the ratio of the linear dimensions of the plan to the linear dimensions of the ground—e.g. 1 to 1000, 1 to 10,000—and are shown on the map by a representative fraction (written R.F.), *e.g.* $\frac{1}{1000}$, $\frac{1}{10000}$. This means that the distance between any two points on the map is $\frac{1}{1000}$th or $\frac{1}{10000}$th of the same distance on the ground. We also show the scale of our maps by a R.F., by drawing the scale on the plan, and by a verbal description. (See Fig. 41, p. 54.)

The numerator of the R.F. is always 1, and is usually taken in the United Kingdom to mean 1 inch. In this case the denominator is expresed in inches too. If the R.F. of a map is $\frac{1}{10560}$, then 1 inch on the map = 10,560 inches on the ground = 6 inches to the mile.

Example.—1. To find the R.F. of a scale of 3 chains to the inch.

One inch on the plan = 3 chains or 2376 inches on the ground.

$$\therefore \text{ R.F.} = \frac{1}{2376}$$

2. To find the R.F. of a scale which is 25·344 inches to 1 mile.

$$\text{R.F} = \frac{25{\cdot}344}{1 \text{ mile}} = \frac{25{\cdot}344 \text{ inches}}{63360 \text{ inches}} = \frac{1}{2500}$$

The scales generally required for ordinary estate work are 1, 2, 3, 4, 5, 6 chains to 1 inch with offsets, and the $\frac{1}{2500}$ and

$\frac{1}{10560}$ (6 inches = 1 mile) ordnance scales. In purchasing scales one should get them 12 inches long, 1¼ inch broad, and about ⅛ inch thick, made of boxwood and of flat section. (Fig. 42.)

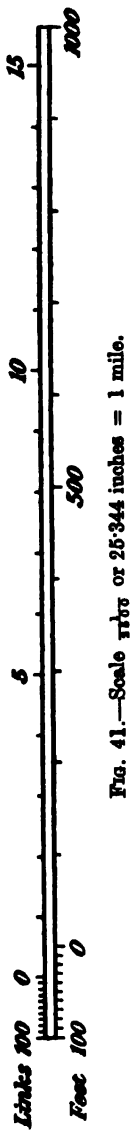


Fig. 41.—Scale $\frac{1}{10560}$ or 25·344 inches = 1 mile.

The total length of 12 inches is divided into 12 equal parts or inches, and each inch is subdivided into 10, 20, 30, 40, 50, 60 parts, each part representing 10 links. Thus in the first case 1 inch represents 100 links or 1 chain, in the second, 200 links or 2 chains, in the third, 300 links or 3 chains, and so on.

The same scales can also be used for 10, 20, 30, 40, 50, 60 feet to 1 inch, which is very convenient for plotting level sections where the horizontal measurement is (say) 1 chain to the inch and the vertical 10 feet to the inch.

The offsets, which are always provided with the scales, consist of short lengths (2 inches long × 1¼ inch broad × ⅛ inch thick) of exactly similar form and divided like the scales with which they are to be used. The only difference is that the divisions go right to the end, which enables offsets to be plotted the more easily at right angles to the chain line. (For use see chapter on Plotting.) The construction of the $\frac{1}{2500}$ and $\frac{1}{10560}$ scales is the same, but in the former a foot is divided into 25 main parts on the feet side, each of which represents 100 feet; each main part is divided into 10 parts, any one of which represents 10 feet.

Fig. 42.

The links side of the scale is divided so that the dimensions may be scaled from the same plan in chains and links, each main division representing 1 chain. It will be noticed that the space representing 1 chain is just the same length as that representing 66 feet on the feet side.

In scales with chains on one side and feet on the other, when the numbered side represents links then the side marked 'feet' represents *feet to the same scale.* If the numbered side represents inches or feet, or anything except links, then the 'feet side' represents nothing in particular. Most scales, are marked '1 Chain to Inch' on one side, and 'Feet' on the other, thus enabling a plan to be scaled off in chains or in feet: this can easily be seen, for it will be found that 66 feet on the feet side is exactly the same length as 1 chain on the other. (Fig. 43.)

Ordnance Survey Scales.—The following are the scales used on the Ordnance Plans of Great Britain :—

$\frac{1}{1000000}$ or 15·782 miles to 1 inch.
$\frac{1}{633600}$ or 10 miles to 1 inch.
$\frac{1}{253440}$ or 4 miles to 1 inch.
$\frac{1}{126720}$ or 2 miles to one inch.
$\frac{1}{63360}$ or 1 mile to 1 inch.
$\frac{1}{10560}$ or 6 inches to 1 mile.
$\frac{1}{2500}$ or 25·344 inches to 1 mile.
$\frac{1}{1056}$ or 60 inches to one mile.
$\frac{1}{528}$ or 120 inches to 1 mile. } Town Maps.
$\frac{1}{500}$ or 126·720 inches to one mile.

Of these, the most useful to us are :—

1. *One inch to the mile* (80 chains = 1 inch) being a *general map* of the whole of Great Britain and Ireland. The New Series map is published in four forms, in sheet 18″ × 12″ :—

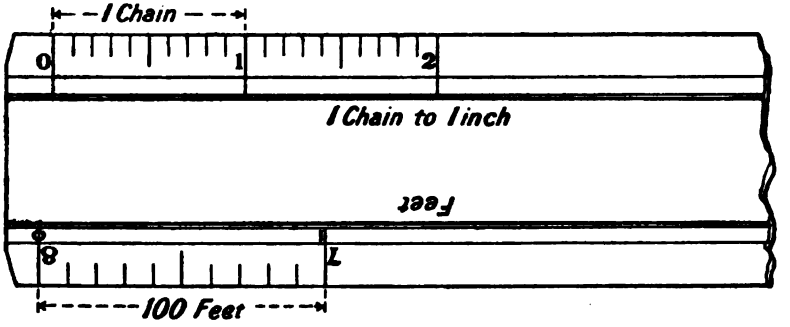


Fig. 43.

(*a*) In outline with contours.
(*b*) With hills shaded in brown.
(*c*) ,, ,, ,, ,, black.
(*d*) Coloured, water blue, hills brown, roads sienna, contours red, woods green.

(*a*), (*b*), and (*c*) cost 1*s.* per sheet ; if cut into sections and mounted to fold for the pocket 1*s.* per sheet extra ; two or more sheets mounted together 9*d.* per sheet.

(*d*) costs 1*s.* per sheet on paper, 1*s.* 6*d.* each mounted ; cut into sections and mounted 1*s.* extra per sheet ; two or more sheets mounted together 9*d.* extra per sheet.

This map is too small to show much detail, and is of use chiefly as a road map. It shows all roads, indicating their character and

whether metalled or not, footpaths, hills, rivers, towns, villages, railway stations, county and parish boundaries.

2. *Six inches to the mile* (13·3 chains = 1 inch) being a *county map* of the whole of the United Kingdom. A full sheet, 36″ × 24″, contains an area of 6 miles by 4 miles, i.e. 15,360 acres, and costs 2*s*. 6*d*. The quarter-sheets are each 18″ × 12″, and contain an area of 3 miles by 2 miles, i.e. 3,840 acres, and cost 1*s*. each.

These maps for Great Britain show much more detail than the general map. They are not large enough for accurate work to be set out from them, but are very useful for estate purposes. Woods, rough pasture, rocks, cliffs, and foreshore are shown in character. Houses, parks, mud, and sand are shown by ruling and stippling. Latitude and longitude are shown on the margins. Contours are shown at 50 feet, 100 feet, and continuously 100 feet intervals up to 1000 feet above the sea level. Altitudes are shown, as on the 25-inch maps, where space permits.

3. 25·344 *inches to the mile* (3·156 chains = 1 inch) being a *parish map* of the whole of the cultivated districts of Great Britain. A square inch on this map approximately equals one acre. It is useful to remember that the diameter of one halfpenny equals one inch.

The size of each sheet is 38″ × 25¼″, and it contains an area of 1½ miles by 1 mile, or 960 acres. Houses are shown ruled or stippled and areas are given. Levels of **bench** marks along the roads, and surface levels, are shown, but not contours. Price 3*s*.

This is the best size for general work. It is usually called the 25-inch map, but is really such that any line drawn on the plan is $\frac{1}{1500}$th of its true length on the ground, and is more correctly described as the $\frac{1}{1500}$ scale. It equals nearly 3·157 chains to the inch.

4. 126·72 *inches to the mile*, being a *town map* of all towns of 4,000 inhabitants and upwards. Each sheet represents 24 chains by 16 chains and contains 38·4 acres. This map is sufficiently large to show doorsteps, the thickness of walls, the divisions between buildings, hydrants, lamp posts, sewer manholes, gratings, levels and bench marks. Size about 38″ × 25¼″. Cost 2*s*. 6*d*. each.

Numbering of the Sheets.—In ordering the Ordnance Survey maps it is necessary to be acquainted with the system on which they are prepared, or one will probably not make clear what one wants. The following notes on the subject have been taken from the description of scales, characteristics, &c., of the Ordnance Survey Maps of the United Kingdom by kind permission of the Director-General of the Ordnance Surveys, 1914.

The sheet lines of the 1-inch maps are independent of those of the maps on the larger scales. The 1-inch maps have one meridian for the whole of each country; for instance, the meridian for the

1-inch maps of England is a line passing north and south through Delamere Forest, and the whole of the new series 1-inch sheet lines for England are drawn parallel and perpendicular to that meridian line. The numbers of the 1-inch sheets therefore for England run continuously from Northumberland to Cornwall.

But for the larger scales the maps are prepared by counties, starting with the 6-inch maps; and each county, or group of counties, where it was found more convenient to group them, has its own meridian. For Hampshire, for instance, the meridian is a line passing north and south through Dunnose, in the Isle of Wight, and all the 6-inch sheet lines for Hampshire are drawn parallel and perpendicular to that meridian line. It follows that the 25-inch and 10-feet sheet lines for Hampshire must also be parallel and perpendicular to that meridian line. The next consideration is that all the large scale plans of the survey are reduced to the smaller scales by photography; towns, for instance, are not surveyed once for the 10-feet scale and again for the 25-inch and the 6-inch scales; but the original plans prepared for the 10-feet scale are reduced by photography to 25-inch plans, and these reduced 25-inch plans are again reduced to 6-inch plans. For convenience in this reduction and also for convenience in numbering the plans, it was decided that all the plans on the two larger scales should, when reduced to the 6-inch scale, fit into the 6-inch sheets. The proportion of the 25-inch or $\frac{1}{2500}$ scale to the 6-inch or $\frac{1}{10560}$ scale being nearly as 4 to 1, each 6-inch sheet, containing an area 6 miles by 4, was divided into 16 25-inch plans, each containing an area $1\frac{1}{2}$ miles by 1; and similarly the proportion of the town or $\frac{1}{500}$ scale to the 25-inch, or $\frac{1}{2500}$ scale, being as 5 to 1, each 25-inch plan containing an area 120 chains by 80 (or $1\frac{1}{2}$ miles by 1) was divided into 25 town plans, each containing an area 24 chains by 16, whenever a town happened to come within the area of the 25-inch plan. The basis of the numbering on the above system for plans larger than the 1-inch is thus the number of the 6-inch sheet for the county; when the 6-inch sheet only is wanted only one number is required; when a 25-inch sheet is wanted the numbers of the 6-inch and 25-inch sheets are both required; and when a town plan is wanted the numbers of the 6-inch, 25-inch, and town plan are all required for ordering the town plan, all these numbers being referred to the county in which the place is situated for which the plan is required. The above notes will perhaps enable the diagram given on p. 58 to be more easily understood, the only point to be added being that, as will be seen from the diagram, and as has been stated under the head of the 6-inch map, the 6-inch sheets themselves are now published in quarter sheets, each containing four 25-inch plans, instead of in full sheets, each containing sixteen 25-inch plans, and that these quarter sheets are distinguished by the letters N.W., N.E., S.W., and S.E., following the number of the 6-inch sheet of the county. But the numbers of the 6-inch, 25-inch, and 10-feet plans remain as above explained.

Fig. 44 shows a 6-inch sheet with the $\frac{1}{500}$ plans, $\frac{1}{1250}$ plans, $\frac{1}{2500}$ plans, and quarter sheets in position (24 square miles) :—

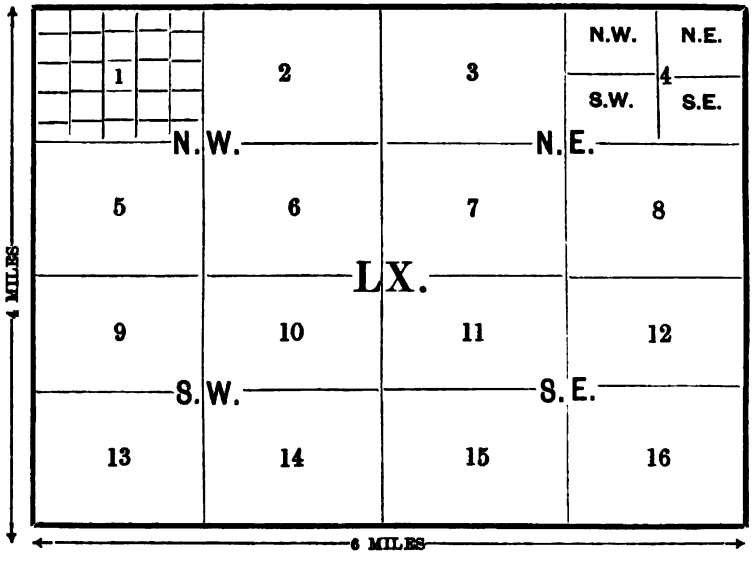


Fig. 44.

The 6-inch sheets of each county are numbered from north to south generally (but not always) by Roman numerals, *e.g.* LX.

In Scotland there are a few cases in which two counties have the same series of numbers, and also a few cases in which one part of a county has a different set of numbers from the other part.

The outer lines of the above diagram represent one full 6-inch sheet, the 6-inch quarter sheets are composed of four $\frac{1}{2500}$ plans, and bear the numerals of the full sheet of which they form a part, with the addition of the initial letters N.W., N.E., S.W., S.E., according to the position they occupy on the full sheet, e.g. Quarter-sheet LX. N.E. on the above diagram includes plans 3, 4, 7, and 8.

The $\frac{1}{2500}$ plans, of which it will be observed there are 16 in the above diagram, are numbered 1 to 16, in arabic figures, and in speaking or writing of any one of them, it is quoted thus :— e.g., LX. 9.

There are four $\frac{1}{1250}$ plans in a complete $\frac{1}{2500}$ scale plan, as shown in the above diagram, see Plan LX. 4 in the N.E. corner, each being identified as the N.W., N.E., S.W., or S.E. corner, as the case may be, e.g., LX. 4. N.W.

There are 25 plans of the $\frac{1}{500}$ scale in one $\frac{1}{2500}$ scale plan,

as shown in the above diagram, see plan LX. 1 in the N.W. corner, they are numbered from left to right on the same principle as that adopted for numbering $\frac{1}{1500}$ plans, and in speaking or writing of any one of them it is quoted thus :—e.g., LX. 1. 9.

The ordnance maps do not profess to show either the limits or the areas of private property : the ordnance surveyors have no means of ascertaining them with any authority. Areas are computed to the centre of the fence, or other boundary of enclosure, except in the following cases :—

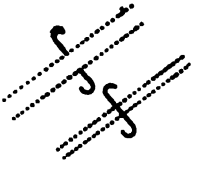
1. When the boundary of a parish, or other civil division does not follow the centre of the fence along which it runs, the area is calculated to the parish or other boundary, and not to the centre of the fence.

2. The fences, &c., bounding either side of a railway are included wholly within its area.

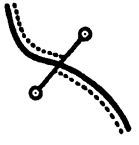
CHARACTERISTICS AND SYMBOLS (FOR GREAT BRITAIN).

Site of antiquities . . . . .

Bench Mark (B.M.) . . . . .

Braces, indicating that the spaces so connected are included in the same reference number and area. . . . . 

Arrow showing direction of flow of water

Change of boundary, indicating the point at which a boundary changes from one description to another : as from F.W. (face of wall) to R.H. (root of hedge). . . . . 

Levelling picket . . . . .

Trigonometrical station . . . . .

An arrow is also used to show connection between reference number and area and small enclosures, wherein the area could not for want of space be shown.

Where to be obtained.—Ordnance maps may be purchased of Edward Stanford, 12, 13, 14, Long Acre, London, W.C.

To find the Area, from a plan, of a figure bounded by Irregular Lines.

There are various methods :—

1. By dividing its boundaries into a number of short lengths, each of which shall be as nearly as possible straight : then treating the whole figure as being bounded by so many straight

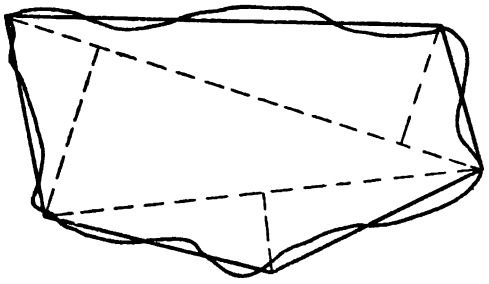


Fig. 45.

lines, dividing it into triangles, and calculating the area of each triangle as described in Chapter 1.

2. By the formation of a polygon whose sides follow the boundaries as nearly as possible, working out the area of the polygon and of the spaces between its sides and the boundaries, and adding or deducting the results as required.

3. By laying down 'equalising' or 'give and take' lines, i.e. straight lines which straighten the boundary by taking in as much as they leave out (see Fig. 45). The area of the polygon will then be equal to the area of the survey. This method is sometimes called 'casting,' and is frequently adopted.

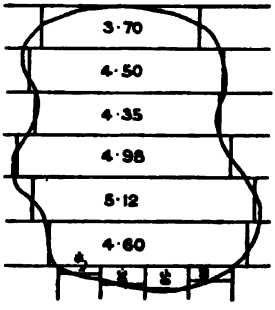


Fig. 46.

4. By means of parallel lines, 1 chain apart. (See Fig. 46.)

Draw a straight line touching the top of the figure; next draw lines parallel to this line at one chain apart according to the scale of the plan : then draw cross parallels as shown at the bottom of the figure in order to deal with those parts which are less than 1 chain wide. Now draw give-and-take lines to equalise the boundaries. Measure the lengths between these equalising lines and add them together; and the result is the area in square chains.

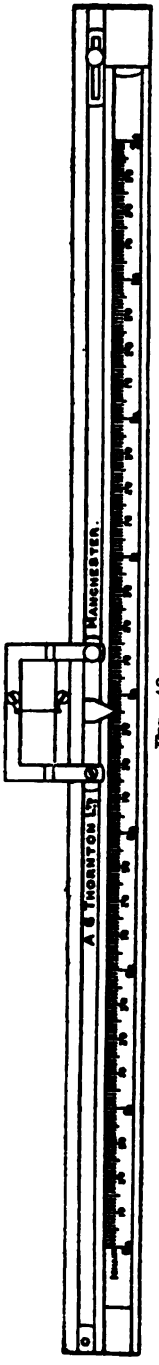


FIG. 48.

Example.

3·70	chains.	
4·50	,,	
4·35	,,	
4·98	,,	
5·12	,,	
4·60	,,	
·30	,,	
·50	,,	
·36	,,	
·15	,,	
28·56	,,	= 2·856 acres = 2 A. 3 R. 17 P.

If the drawing of these lines is likely to damage the plan, then a piece of tracing paper can be pinned over the plan and the lines drawn on this. This is an accurate and easy method of ascertaining areas of difficult shape.

5. *By Simpson's Rule.*—Divide the line AB up into an *even* number of equal parts, and take offsets

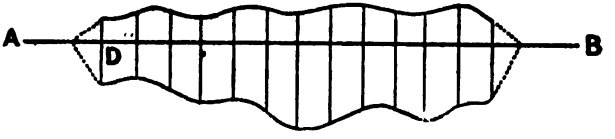


FIG. 47.

from each of these divisional points to the curved boundary, i.e. an odd number of ordinates. (See Fig. 47.)

Then—

Area = (first offset + last offset + 2 × sum of all other odd offsets + 4 × sum of all the even offsets) × ⅓ of the common distance D between the two adjacent offsets.

This rule, which is based on the assumption that the curved boundaries of the figure consist of short parabolic arcs, gives accurate results.

6. *By the Computing Scale.*—This very useful instrument is generally divided so as to measure the areas of figures to one or two scales only, but a *Universal Computer* has been designed to overcome this difficulty. With the latter only one computing frame is required, and as many scales as are wanted, such as 1, 2, 3, 4, 5, 6, chains to the inch, 6 inches to the mile and 25·344 inches to the mile can be inserted. (See Fig. 48.)

To use the instrument a sheet of tracing cloth is required which is ruled with lines at a distance of one

chain apart for scales of 1, 2, 3, 4 chains to the inch. For smaller scales the distance between the lines should be ruled to ¼-inch spaces and the computer divided to read to this.

This piece of transparent paper (generally made of horn paper, as tracing cloth is not sufficiently firm) is placed over the plan in such a way that the area to be computed lies exactly between the parallel lines (see Fig. 49). Fix the paper with weights or pins so that it does not slip.

The area is now divided up into strips of 1 chain in width, so that by adding together the lengths of each strip we arrive at the area.

Place the computer upon the horn paper, so that the scale is parallel to the lines on it, and the wire on the slide with its index at zero is in the position AB, thus equalising the boundary as shown. Now move the index to the position CD. Move the scale bodily, with the reading of the index left upon it, and place it so that the wire is in the position EF sliding it along as before to GH. Proceed thus to the end. If the full length of the scale is used before the area is covered, make a mark on the sheet and note on a piece of paper the area already arrived at. Begin with the index at zero where you left off and proceed as before until the whole area has been covered.

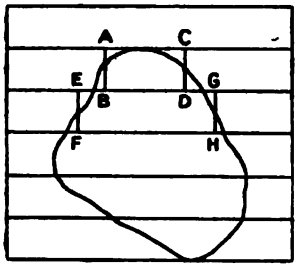


FIG. 49.

Computing sheets can be obtained from the instrument makers for the several scales required, thus saving the trouble of ruling. It is a most useful instrument.

By the Planimeter.—This instrument, invented by J. Amsler, is of a delicate nature and does not as a rule find a place in the estate office.

If it is of the *fixed* kind it gives the result in inches, if of the *proportional* kind the bar must first be set to suit the nature of the computation. The following instructions are given by the makers, and are reproduced here by their kind permission.

No. 1 Planimeter (brass) and No. 2 Planimeter (german silver), arranged for measuring areas in square inches (or other unit if specially desired).

Needle-point outside the diagram.—Put the instrument on the drawing surface, set the tracing point F at a mark on the outline of the area, press the needle-point E slightly into the paper outside the curve, and read off the roller D and the counting wheel G taking the whole circumference of the recording roller as unit of reading (the roller need not be set to zero).

Readings.—The drum of the roller is divided into 100 parts. The tenths of a part are read on the vernier. The complete turns of the roller are read on the counting-disc which advances one line at every such turn. The counting-disc performs one revolution at every 10 turns of the roller.

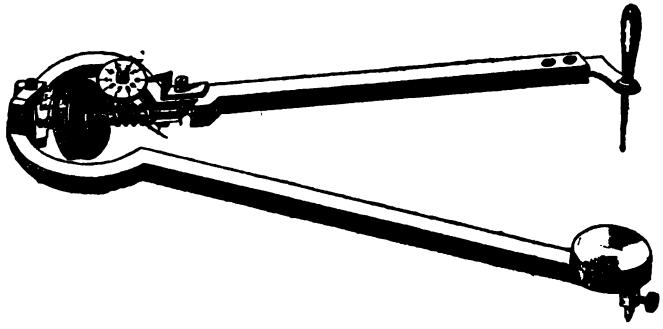


FIG. 50
Range: Circle of 18 inches diameter.

Each complete reading is a figure of four digits, the units being read on the counting-disc, the tenths and hundredths on a drum, and the thousandths on the vernier.

The reading of the roller and disc, shown for example in the adjoining figure, is 5·343.

(The zero of the drum and a mark of the disc should simul-

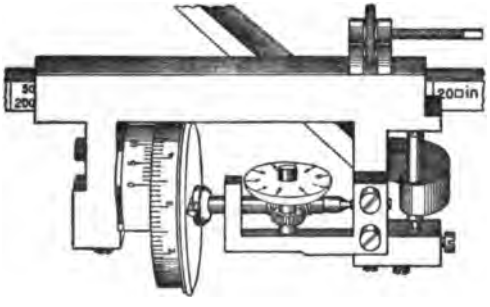


FIG. 51.

taneously be opposite the fixed index mark. This is never exactly the case in consequence of the imperfection of the worm wheel-gear, and this should be taken into account in making readings in the same way as with a watch, when the minute-hand points to 12, whilst the hour-hand fails to indicate the exact hour.)

Then move the tracing-point F round the area in the direction

of the movement of the hands of a watch, till it reaches again the starting point. Now take another reading and subtract the first from the second reading. The difference multiplied by 10 will then be the area of the curve in square inches.

Example.—To measure the area of a square of 4 inches side.

Result : Second reading 3·073
First reading — 1·473

1·600 × 10 = 16 sq. ins.

If the reading before starting had been 9·521 then the reading after circumscribing the same square as before would be 1·121. As the travel of the roller is in both cases the same, it is evident that the zero mark of the wheel has passed the fixed index-mark and that, consequently, the second reading has now to be supplied with one more digit on the left before subtracting the first reading. Thus—

Complete second reading 11·121
First reading — 9·521

1·600 × 10 = 16 sq. ins.

Needle-point inside the diagram.—Circumscribe the diagram with the tracing-point in the direction of the movements of the hands of a watch, watching at the same time the counter in order to see whether the total rotation of the roller is a forward or a back motion.

This preliminary rough operation being completed, proceed as before explained, now following the curve *carefully* with the tracing-point. If the total rotation of the roller has been a *forward* motion, subtract the first from the second reading and *add* the difference to the figure engraved on the top of the small weight used for keeping the needle-point in its place. The sum multiplied by 10 will then be the area of the curve in square inches.

Example.—To measure a circle of 18 inches in diameter. (You will see that the total rotation of the roller is forward.)

Result : Second reading 9·884
First reading — 0·868

9·016
Figure on weight + 16·431 (This figure is slightly different for different instruments.)

25·447 × 10 = 254·47 sq. ins.

If the total rotation of the roller is a *back* motion, subtract the second from the first reading and *subtract* the difference from the figure on the weight.

Example: To measure a square of 11 inches side. (You will see that the total rotation of the roller is backward.)

Result:	Complete first reading	13·009
	Second reading	− 8·678
		4·331
	Figure on weight	16·431
	Difference of readings	− 4·331
		12·100 × 10 = 121 sq. ins.

Note.—When the mark 0 on the roller is at the mark 0 of the vernier a mark of the counting-wheel should be opposite the fixed index-mark. Any slight noncoincidence due to imperfection of worm-wheel gear may readily be allowed for in taking readings.

The area corresponding to a total revolution of the roller—10 square inches in the above example—is engraved on the weight along with the figure before mentioned.

No. 8 Planimeter (brass) and No. 4 Planimeter (german silver), arranged for measuring areas in either or several units (English and French) scales.

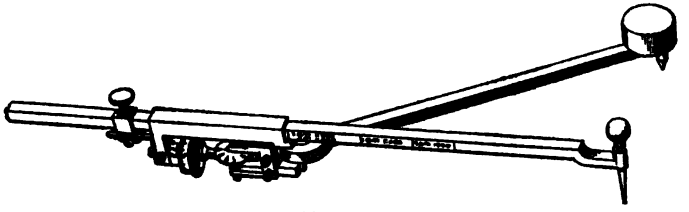


FIG. 52.
Range: Circle of 24 inches in Diameter.

Set the index-mark J on the bevelled edge of the slide to a convenient division on the bar. There is a clamp and fine adjustment to get this position exactly. The number of units of area per unit of reading and the nature of unit or scale are marked to the right of each division.

The divisions on the bar are the following:

on back—

		200 ac 6″ = 1 mi	10 ac 1 : 2500 0·4 ac 1 : 500	5 ac 1 : 2500

on top—

20·811	20·818	21·042	22·107 22·122	

on front—

100 □ cm	100 □′ $\frac{1}{8}$″ = 1′	200 □′ $\frac{1}{4}$″ = 1′ 50 □′ $\frac{1}{2}$″ = 1′	10 □in	100 □′ $\frac{1}{4}$″ = 1′ 400 □′ $\frac{1}{2}$″ = 1′

(The figures on the top of the bar are slightly different for different

instruments. The denotation □′ means square foot, □ cm. = square centimeter, □ in = square inch, ac = acre, mi = mile.)

If specially desired other divisions instead of these are put upon the bar, without extra charge.

The slide being set on the bar, place the instrument upon the drawing and measure the diagram as with No. 1 planimeter.

Example: To measure a circle of 5 inches in diameter on a $\frac{1}{4}''$ plan.

Set the index-mark J on the slide to the division 200 □′ $\frac{1}{4}'' = 1''$, press the needle-point E *outside* the circle into the paper, set the tracing-point F to any mark of the circle, read off the counter—the reading may be 1·322—follow the circle with the tracing-point until you arrive at the starting point and again read off the counter. The reading will then become 2·893.

Result: Second reading 2·893
First reading − 1·322

1·571 × 200 = 314·2 square feet.

(The multiplier 200 is identical with the figure close to the right of the division used.)

For measuring small diagrams drawn on the $\frac{1}{2}''$ or $\frac{1}{8}''$ scale, the slide may conveniently be set to the last division on the bar marked 100 □′ $\frac{1}{2}'' = 1'$
400 □′ $\frac{1}{8}'' = 1'$.

If the needle-point E be placed *inside* the diagram to be measured, then one of the figures on the top of the bar must be used in the same way as the figure on the weight of No. 1 planimeter.

Example.—To measure a square of 12 inches side on an ordnance map (scale 1 : 2500).

Set the index-mark on the back of the slide to the division 10 ac 1 : 2500.

Suppose that the counter reads 2·482 before starting the tracing-point.

In following the outline of the square you will see that the total rotation of the counter is backward and that the zero-mark of the counting-wheel passes once the fixed index.

Result: Complete first reading 12·482
Second reading − 4·723

7·759

Figure on top of bar just over the division 22·107
Difference of readings − 7·759

14·348 × 10 =
143·48 acres.

(The multiplier 10 is identical with the denotation 10 ac close to the right of the division used.)

No. 5 Planimeter (german silver), arranged for measuring very large and very small areas.

1. For measuring **large areas** set the slide B to the proper division on the bar A. For doing this, hold the bar A with the right hand and shift the slide with the left whilst the parallelogram hangs down.

Then place the instrument upon the drawing and proceed exactly as with No. 3 planimeter.

The sliding-point *f* is of no use now and may be taken off.

2. For measuring **small areas,** the smaller sliding-bar *a* is to be adjusted so that the proper mark on the bar comes even with the end-face of the tube in which the bar slides (the slide B need not be adjusted upon the bar A). Then let the point *f* travel round the diagram by leading the point F with the hand, but following the point *f* with the eye. This can be done with great ease and accuracy the two points *f* and F describing nearly similar paths.

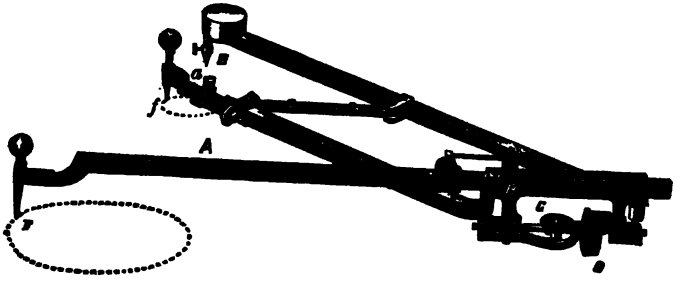


FIG. 53.

Range of Tracing-point F: Circle of 38 inches Diameter.

The area will then be expressed in the unit shown at the mark on bar *a*.

Small areas can be measured in this way with the same accuracy as large areas.

No. 6 Planimeter (german silver) same as No. 4, but with special arrangement for finding rapidly the mean height of indicator diagrams.

No. 6 planimeter can be used for measuring areas in exactly the same way as No. 3 planimeter.

For measurements of areas the large size bar is provided with the same divisions as No. 4 planimeter.

For finding the mean height of an indicator diagram take, by shifting the slide on the bar and keeping the planimeter upside down, the diagram lengthwise between the steel points on the upper side of the instrument. Then place the planimeter without altering the relative position of slide and bar in the usual way upon the drawing—needle-point outside the diagram—and follow the outline

of the diagram with the tracing-point. The difference of the readings at the beginning and at the end of the operation divided by 0·4 will be the mean height of the diagram, expressed in inches.

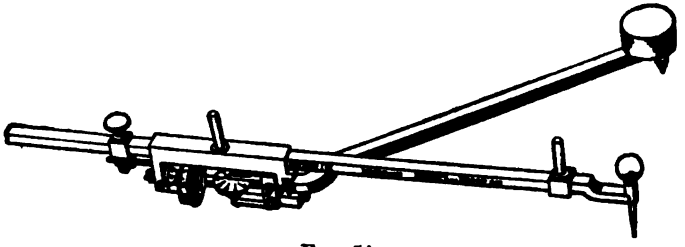


FIG. 54.

No. 6 Planimeter. Large Size—Range: Circle of 25 ins. in diameter; Length of Diagrams: 2–8 in. Small Size—Range: Circle 14 ins. in diameter; Length of Diagrams: 2–5 ins.

Example.—Second reading 2·361
First reading − 1·913

0·4) 0·448 = 1·12 ins. = mean height.

If the diagrams for up and down stroke are measured jointly, divide by 0·8 instead of 0·4.

Mean pressure = Mean height × Scale of spring of indicator. Supposing the scale of the spring in the above example is 1″ = 80 lb. per square inch, then—

$$\text{Mean pressure} = \frac{0{\cdot}448 \times 80}{0{\cdot}4} = 89{\cdot}6 \text{ lb. per sq. in.}$$

The number of pounds per inch of height being usually a multiple of 4, the arithmetical work is thus extremely simple.

If desired, a special *screw* is supplied with this instrument for *lifting* the tracing-point from the paper so as to allow of an exchange of diagrams without disturbing the reading of the roller. (Fig. 55.)

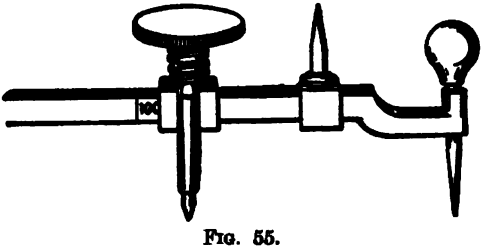


FIG. 55.

This auxiliary screw is very convenient when a great number of diagrams of equal length are to be computed. During the travel of the tracing-point, the point of the screw should not touch the paper. For exchanging the diagram the screw must be lowered a

little so as to lift the tracing-point from the paper. The diagram can now be removed and another slid at its place. This operation does not affect the roller, and the final reading obtained on the first diagram may be used as the initial reading for the measurement of the second diagram. In this way the roller is to be read off but once for each diagram.

To obtain the Area of a Survey made with Incorrect Chain.—Plot the survey and calculate the area as if the chain were correct. Then—

(Correct chain)^2 : (chain used)^2 : : Area of plan calculated : Correct area of plan.

Example.—A chain which had stretched 3 links was used to make a survey and the area of the plan when plotted worked out at 10 acres. What is the correct area ?

Then— $(100)^2 : (103)^2 : : 1{,}000{,}000$: Correct area.

$$\therefore \text{Correct area} = \frac{10609 \times 1000000}{10000}$$

$$= 10609 \times 100$$

$$= 1060900 \text{ square links}$$

$$= 10{\cdot}609 \text{ acres}$$

$$4$$

$$2{\cdot}436$$

$$40$$

$$17{\cdot}440$$

$\therefore$ Correct area = 10 acres 2 roods 17 perches.

Areas by different Scales from Plan.—When the scale to which the plan has been drawn is not to hand, it is possible to arrive at the area by a different scale from that of the plan.

Example.—Suppose we have a plan whose scale is 3 chains to an inch, and we computed the area with a 1 chain to the inch scale, making it 10 acres. What is the true area ?

Now 3 chains to the inch is much smaller than 1 chain to the inch, so that the area should be greater. If we treat it as a simple proportion sum we shall get the result required. But the point to remember is that it is necessary to use the *square of the scale*, as we are dealing with areas, and to state it as follows :—

$$1^2 : 3^2 : : 10 : \text{correct area}$$

$$\therefore \text{Correct area} = \frac{9 \times 10}{1}$$

$$= 90 \text{ acres}$$

and *not* $1 : 3 : : 10 : x$.

Also :

The area of a certain piece of land is 10 acres. We computed

the area from the plan with a 3-chain scale and the result was $22\frac{1}{2}$ acres. What is the scale of the plan?

$$22{\cdot}5 : 10 :: 3^2 : \textit{square of scale required}$$

$$\therefore \textit{Square of scale required} = \frac{10 \times 9}{22{\cdot}5}$$
$$= 4$$

$$\therefore \textit{The scale is 2 chains to 1 inch.}$$

Scale of Plan.—It is necessary to consider to what scale the survey is going to be plotted before starting the survey, in order to know to what degree of accuracy measurements should be made. Now $\frac{1}{80}$th of an inch can be shown distinctly upon paper, so that if the scale be 80 feet to an inch, we must read the chainage and offsets accurately to the nearest foot; but if the scale be 400 feet to an inch, it would be impossible to show any distance less than 5 feet long on the plan, and it would not be necessary to measure smaller distances than 5 feet. Supposing the limit of accuracy, however, to be $\frac{1}{100}$th of 1 inch, then in the following scales this equals—

1 chain	to	1 inch	=	1 link
2 chains	,,	,,	=	2 links
3	,,	,,	=	3 ,,
4	,,	,,	=	4 ,,
5	,,	,,	=	5 ,,
6	,,	,,	=	6 ,,
10 feet	to	1 inch	=	$\frac{1}{10}$ foot
20	,,	,,	=	$\frac{2}{10}$,,
30	,,	,,	=	$\frac{3}{10}$,,
40	,,	,,	=	$\frac{4}{10}$,,
100	,,	,,	=	1 ,,
150	,,	,,	=	1·5 feet
200	,,	,,	=	2 ,,
400	,,	,,	=	4 ,,

1 mile to 1 inch = 80 links *or* 52·8 feet
1 mile to 6 inches = 13·33 links *or* 8·8 feet
$\frac{1}{1500}$ = 3·15 links *or* 2·0833 feet
$\frac{1}{800}$ = 0·631 link *or* 0·417 feet

The Vernier Scale.—This is an auxiliary scale, invented by Pierre Vernier (1580–1637), whereby we are enabled to measure the sub-divisions of any graduated scale. Two plain scales are required, one called the *Primary*, the other the *Secondary* or *Vernier*.

The number of divisions on the vernier may be either one less or one more than the number taken on the primary. Consequently, if we take a length of (say) 12 equal divisions on the primary

and divide this into one less or one more divisions for the vernier, then each division of the vernier is $\frac{1}{9}$ths or $\frac{1}{11}$th of each division of the primary: that is to say, that the difference between one division on the primary and one division on the vernier is $\frac{1}{11}$th of the primary division.

Expressed algebraically.

Let a = the value of one division of the primary,
and b = „ „ „ „ „ vernier.

If the vernier divisions be the larger:

Then n = the number of divisions on the vernier,
and $n + 1$ = „ „ „ „ primary.

$$(n + 1)a = nb$$
$$\therefore na + a = nb$$
$$\therefore n(b - a) = a$$
$$\therefore b - a = \frac{a}{n}$$

And if the vernier divisions be the smaller:

Then n = the number of divisions on the vernier.
and $n - 1$ = „ „ „ „ primary.

$$(n - 1)a = nb$$
$$\therefore na - a = nb$$
$$\therefore na - nb = a$$
$$\therefore n(a - b) = a$$
$$\therefore a - b = \frac{a}{n}$$

Thus $b - a$ or $a - b$ = the degree of accuracy to which the scale may be read.

The Vernier of the Theodolite.—Instruments for measuring angles have verniers attached to them. Such instruments are the box sextant, theodolite, &c.

Take the case of an ordinary transit theodolite (see p. 175) reading to one minute of accuracy. It will be found that in a length of 14° 30′ on the primary scale there are 29 divisions. This length on the vernier is divided into 30 divisions: therefore each division $= \frac{29}{30}$ of a division on the primary, i.e. $\frac{29}{30} \times 30' = 29'$; so that there is a difference of 1 minute (30 − 29) between the scales of the primary and the vernier. Or $a - b = \frac{a}{n} = \frac{30'}{30} =$ 1 minute, degree of accuracy to which the scale reads.

The *length* of the vernier and the minuteness of the graduation of the primary scale will determine to what degree of accuracy angles may be read. It will be found in some instruments that the primary scale of the lower limb is divided into degrees and

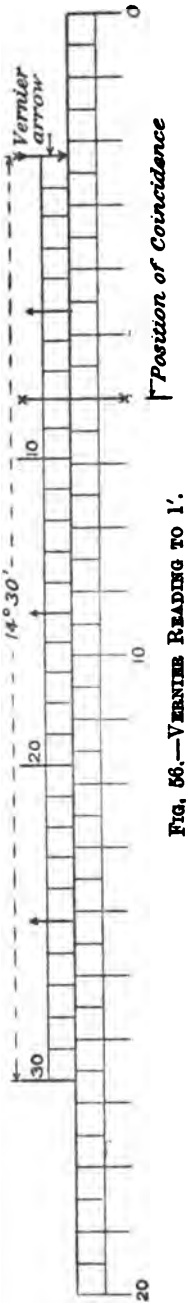


FIG. 56.—VERNIER READING TO 1'.

half degrees, and the length of the vernier is 29° 30′. This length is divided into 60 parts: therefore the length of each division of the vernier is—

$$\frac{29°\ 30'}{60} = \frac{1770}{60} = 29\tfrac{1}{2}'$$

Now, the divisions on the lower limb are 30′, and the difference is $30' - 29\frac{1}{2}' = \frac{1}{2}' = 30''$: therefore the vernier reads to 30″. Or $a - b = \frac{a}{n} = \frac{30'}{60} = \frac{1}{2}' = 30''$, degree of accuracy to which the instrument reads.

Again, supposing the lower limb is divided into degrees and $\frac{1}{3}$ degrees, and the length of the vernier is 19° 40′, which length is divided into 60 parts. Then—

Each division of the vernier

$$= \frac{19°\ 40'}{60} = \frac{1180'}{60} = 19\tfrac{2}{3}'$$

Now, the divisions on the lower limb = 20′, and the difference is $20 - 19\frac{2}{3}' = \frac{1}{3}'$ or 20″: therefore the vernier reads to 20″. Or $a - b = \frac{a}{n} = \frac{20'}{60} = \frac{1}{3}' = 20''$, degree of accuracy to which the instrument reads.

To find how a vernier should be graduated.—Suppose the lower limb of a theodolite reads to 10′, and it is required to read to 10″, how should the vernier be divided?

In this case $a-b$ must be made 10″: 10″ is $\frac{1}{60}a$.

$$\therefore\ a - b = \frac{a}{60}$$
$$\therefore\ 60a - 60b = a$$
$$\therefore\ 59a = 60b$$

Therefore a length of 59 divisions of the lower limb should be divided into 60 equal parts for the vernier.

How to read the vernier.—Read on the *primary scale* the position of the arrow on the vernier: now look along the vernier until you find a point where a line on the vernier coincides with a line on the primary and read on the vernier its position. Add the two readings together. (See Fig. 56.) Note that the reading

on the primary scale is that of the division next *behind the vernier* and not in advance. The reading of Fig. 56 is 2° 8′.

If the vernier arrow had been between $2\frac{1}{2}°$ and 3° on the graduated limb, and the line of coincidence had been at (say) 18, then the reading would have been 2° 48′.

The difference in the method of reading the two kinds of verniers is (1) when the vernier divisions are the smaller, the scale and the vernier are read *in the same direction*, (2) when the vernier divisions are the larger, the scale and the vernier are read *in opposite directions*. As a general rule in surveying instruments the vernier reads in the same direction as the primary scale, but the figures on the vernier will make it clear in which direction it is to be read.

The 360° on the horizontal limb of a theodolite is called the *zero of the limb* and the arrow is called the *zero of the vernier* or *index*.

To set an angle on the horizontal limb.—Take the case of a theodolite with the graduated lower limb divided into degrees and half degrees. *Set the index of the vernier to the given number of degrees on the lower graduated limb : bring the vernier division corresponding to the given number of minutes to coincide with the next division in advance of it on the lower graduated limb by means of the vernier plate tangent screw.*

Example.—Suppose it is required to set the instrument to an angle of 62° 54′.

Set the index of the vernier to 62° 30′ on the graduated limb and clamp the vernier plate. Now by the slow-motion screw of the vernier plate bring the twenty-fourth division of the vernier to coincide with the next division in advance of it on the graduated limb.

CHAPTER IV

PLOTTING AND PLAN DRAWING

To Plot a Survey.—Pin a sheet of drawing paper on the drawing board and begin by drawing the longest survey line in pencil in such a position that the remaining lines will go conveniently on the paper. It is a good thing to draw first in pencil a north point at the right-hand top corner of the paper, showing the top of the paper as north, and then to set off the direction of the first line with a protractor from the bearing taken in the field by the prismatic compass. (See AB in Fig. 57.)

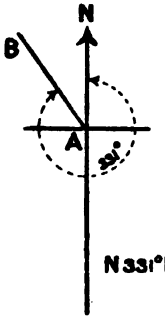


FIG. 57.

Now place the rolling parallel rule against AB and roll it gently into the centre of the paper, and the direction of the first line of the survey can be drawn along its edge. The survey will then be in its relative position with regard to the points of the compass.

It is important when using these parallel rules to use only one hand, with the fingers placed nearly on the middle of the rule, so as to avoid the tendency of one end to move faster than the other. Only the wheels should touch the paper when the rule is moving, and the surface of the paper should be good.

Mark the positions of stations with the scale to which the plan is to be plotted and proceed to lay down the remaining lines by means of a pair of compasses until the whole are drawn and checked by the tie lines.

A triangle is plotted as follows. (See Fig. 58.)

Suppose AB is 3 inches, AC 2 inches, and BC 1½ inches. Draw the line AB 3 inches in length, then with a pair of compasses describe an arc of a circle having A for its centre and 2 inches for its radius, and also one having B for its centre and 1½ inches for its radius. The two arcs will cut one another at C.

If the lines AC and BC be drawn the whole triangle is plotted.

If there are no offsets the boundaries may be inked in and the plan finished, but if there are, proceed to plot them thus :—

Lay the 12-inch scale along the line so that the edge is parallel to it at a distance of 1 inch (or half the length of the small offset scale) from it. This should be carefully done, the beginning of the scale being exactly opposite the beginning of the line. Place a weight on each end of the scale so as to keep it steady. The offset scale may now be used to slide along the 12-inch scale, and the exact position of each point measured may be marked on the paper by means of a fine pencil. (See Fig. 59.) When these offset points are joined by straight lines in pencil they may be inked in, and the boundary is correctly delineated.

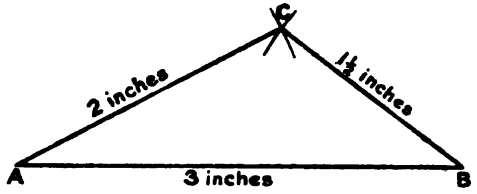


FIG. 58.

All the survey lines and boundaries having first been drawn in in pencil they may be afterwards be inked in, in red for the survey or constructional lines, when these have to be shown, and in black for the boundaries.

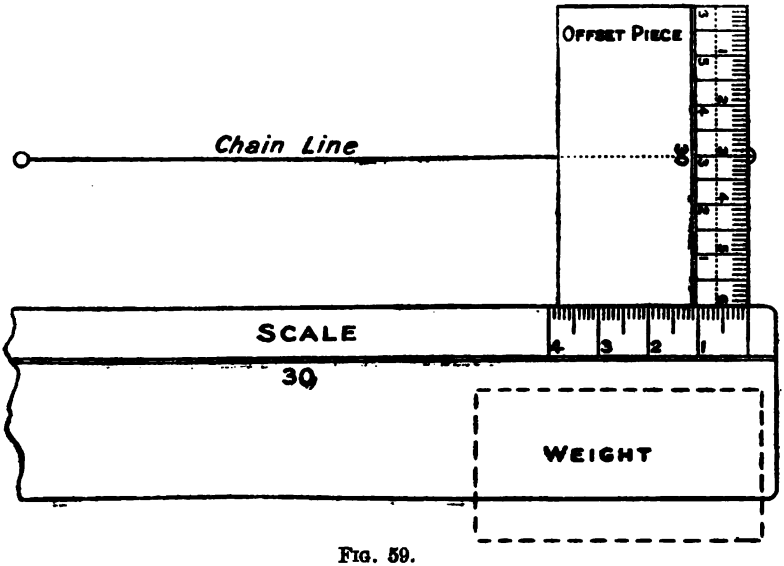


FIG. 59.

Care should be taken to avoid drawing unnecessary lines so as to prevent erasure as much as possible; and when india-rubber is used it should only be rubbed one way and not backwards and forwards. All lines should be drawn from left to right, and it is necessary to avoid pressing the pen against the edge of the set square as it produces an uneven line, and a good line must always

Drawing Papers—List of Sizes

	Weight.	Size.
	lb.	inches.
Antiquarian	240	53 × 31
Grand Eagle	150	42 × 28
,,	210	,,
Double Elephant	133	40 × 26¾
,,	160	,,
,,	210	,,
,,	235	,,
,,	260	,,
Colombier	100	34½ × 23½
Atlas	100	34 × 26
Elephant	72	28 × 23
Imperial	72	30½ × 22½
,,	90	,,
,,	110	,,
,,	140	,,
,,	200	,,
,,	300	,,
Super Royal	52	27 × 19
Royal	44	24 × 19
,,	60	,,
,,	70	,,
,,	80	,,
,,	88	,,
Medium	34	22 × 17½
Demy	25	20 × 15½
Foolscap	15	17 × 13½
,,	18	,,
Cartridge D. Elephant	150	40 × 26¾
,, ,,	210	,,
,, Imperial	72	30½ × 22½
,, ,,	84	,,
,, ,,	110	,,
Cres. Dble. Elephant	210	40 × 26¾
,, Imperial	110	30½ × 22½
Vellum Imperial	130	,,
,, Royal	90	24 × 19
,, ,,	100	,,

24 sheets = 1 quire : 20 quires = 1 ream.

be the same thickness throughout. For ordinary use an HH pencil is best. The degree of hardness is indicated by the number of H's and of softness by the number of B's. When an ordinary drawing is to be made it is sufficient to fasten the drawing paper to the board by means of pins only: but if an important drawing is to be made, it is necessary to glue the edges of the drawing paper to the board, having first damped the whole surface of the paper with a sponge. By this means the paper is well strained.

When one arc of a circle has been described and it is required to determine a point in it by the intersection of another arc, it is only necessary to mark off the point of the latter without drawing the arc: this saves drawing unnecessary lines.

Materials.—Good materials should be used. For plans of importance use Whatman's best drawing paper.

The most used sizes are double elephant, demy, and imperial. For working drawings cartridge paper is good enough, but for finished drawings use Whatman's best, as they bear wetting and stretching without damaging, and take shading and colouring well.

Always draw on the right side of the paper, *i.e.* in the case of Whatman's, the side from which on holding a sheet to the light, the maker's name in watermark can be read; and in the case of cartridge paper, the smooth hard side.

Tracing Paper.—This is useful for making copies of plans for temporary use, but it tears easily.

Tracing cloth is much superior, but is rather expensive, the best costing about:—

——	27″	30″	36″	40″	43″	54″ wide.
Rolls of 22 yards ..	17/6	18/6	21/6	25/9	27/9	37/9 per roll.

A good cloth for general use, however, is supplied by Messrs. Thornton, Paragon Works, Manchester, as follows:—

Rolls of 20 yards—width 30 inches, at 12*s.* 6*d.*; width 40 inches, at 16*s.* per roll.

Indian Ink should be used on tracing cloth as on all drawings. When colouring tracing cloth put the colour on the side opposite to that on which the ink lines are drawn. The colour will go on better when the tracing cloth has been either well rubbed with india-rubber or well dried by the fire.

Rubbing the surface over with french chalk will make the cloth take ink lines better: or a little ox-gall may be put in the ink or colour, but this practice is not recommended.

Colours.—Plans of land are usually coloured all over, the character of each part being shown by some conventional sign. A good draughtsman needs few colours, and it should be remembered

that a surveyor's plan should never be coloured, but tinted. The following will be found to be quite sufficient: Crimson lake, prussian blue, burnt sienna, yellow ochre, Payne's gray, sap green, and light red.

In order to obtain an even surface on large areas it is best to damp the paper before applying the colour. Red sable brushes are better than camel's hair. For putting on washes on large surfaces a large brush is required and the colour must be prepared thin and of sufficient quantity to start with. Commence at the top part of the drawing and gradually spread it downwards as evenly as possible. If deep colour is required, put it on in layers, and not dark all at once. Do not go over the work with a second coat until the first is quite dry.

Drawing Compasses and Dividers (Fig. 60).—The best compasses have a *sector joint* instead of the *long joint*: this lessens the amount of friction and stiffness when the instrument is nearly closed, and

Fig. 60.

the compasses consequently move with equal pressure whether nearly closed or wide open.

Spring Bows.—These are required for describing small circles.

Drawing Pen (Fig. 61).—The drawing pen consists of two blades of brass or electrum ending in steel nibs fixed to an ivory handle. In order to facilitate cleaning one blade is hinged to the other, so that it can be opened and cleaned. The ink should be inserted between the nibs with a piece of paper, and the pen held nearly vertical against the rule so that both nibs touch the paper.

T *Squares* (Fig. 62).—These should be an inch shorter than the length of the drawing-board on which they are to be used.

Set Squares.—These are best made of transparent material. They are of sizes from 4 inches to 16 inches, triangular in form with one angle a right angle, and the others 45° and 45°, 60° and 30°, or 67½° and 22½°.

Beam Compasses.—These are used for striking arcs of long radii. Very often when plotting large surveys at 1 chain and 2 chains to the inch, the lines are too long to admit of an ordinary pair of compasses being used to describe the arc. These compasses have a beam from 2 feet to 4 feet long. Two sockets are fitted to the beam, one is fixed and the other which carries a pencil point can be made to slide up and down and clamped to any length.

Proportional Compasses.—These are used for reducing or enlarging the area of a plan in a given proportion as explained later. They consist of two similar brass or electrum limbs, making a double pair of compasses with steel points A, B, C, D clamped by turning the milled-head screw. (See Fig. 63.)

When closed the limbs appear as one, and in this position the instrument is to be adjusted by moving the slide up or down the groove.

If the index line on the slide is set to the figure 2 on the right-hand side and clamped by the screw E, then any distance marked off by A and B will be half the distance measured by C and D, and so on for the other figures.

The circumferences also of circles may be divided into any number of equal parts up to 20, in the same way.

Fig. 61.

Fig. 62.

Fig. 63

On the other face of the compasses, divisions for plans and solids are marked.

For plans.—If the index on the slide be set to 3, then the area of the square made by the longer points C and D will be three times the square made by the points A and B; and so on for the other figures.

For solids.—Set the index on the slide to any number on the scale of solids; then the distance between the points C and D will give the side of a solid of so many times the content as the number indicates; and the distance between the points A and B will give the reduced side of the solid.

The Protractor.—The protractor most commonly used is semicircular and made of brass or electrum. It has the advantage over the rectangular form, in that in a semicircular protractor any angle is protracted at the full length of the radius of the protractor from the centre, which is not the case with the rectangular protractor. To set off an angle with this protractor, its position will be on the right side of the north line when the bearing is less than 180°, and on the left when the bearing is greater than 180°.

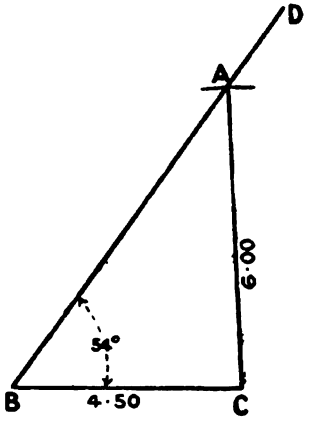


Fig. 64.

To plot a Triangle.—Suppose in the triangle ABC (Fig. 64) the side AC measures 6 chains, the side BC measures 4·50 chains, and the angle at B is 54°. Plot to a scale of 3 chains to one inch. Draw BC 1½ inches long, take the protractor and lay down the direction of the line BD (length unknown) 54° from C. Now from centre C with radius 2 inches describe an arc cutting BD in A. Join AC. Then ABC is the triangle required. (See Fig. 64.)

A large circular protractor with vernier and arm may be used for more important work. This will enable us to measure and plot angles to 1 minute. Fig. 65 shows a one-arm circular electrum protractor, 6 inches in diameter and costing in case about £3. The length of the circumference of a circle equals $2\pi r$, and varies as the length of the radius or the length of the protractor. It depends therefore on the length of the circumference to what degree of minuteness the circle may be graduated. The centre of the protractor in Fig. 65 is made of glass, usually, with fine lines across it. It is therefore easy to place the centre upon the mark. One side of the arm, which is provided with a vernier, forms a radial line from the centre. The straight edge has a point fixed at the end of it which when pressed will make a fine hole in the drawing, thus marking the exact position of the angle according to the reading of the vernier. After removing the protractor this point may be joined by a line to the central mark.

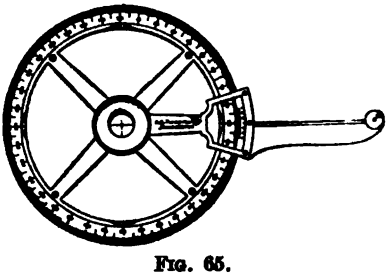


Fig. 65.

The method of using this protractor in plotting surveys made with angular instruments will be shown in a later chapter.

Level Sections.—When plotting level sections, the datum line should be parallel to the lower edge of the drawing paper. Only a T square and set square are required for this part of the work. The datum line is set off with the T square, and the vertical heights above this with the set square, which is used on the T square in a similar way to that described in connection with the plotting of offsets.

The horizontal distances are now scaled off along the datum and the vertical heights along the perpendiculars. If these perpendiculars become inconveniently long, the datum may be assumed to be so many feet *above* the datum of the levels. This distance is noted along the base line and written say—50 feet above datum. (See chapter on Levelling.)

Show Scale on Plan.—In the case of important work it is advisable to draw the scale of the survey on the plan, because paper will expand or contract slightly in spite of the trouble that may be expended in getting it seasoned.

Surveyors' Institution Examination.—In making a survey such as the candidates for the Professional Associateship of the Surveyors' Institution are required to do, the area of the plan should be shown, besides the level sections, north point, and title. In this case where so much has to be shown on one sheet, the draughtsman may make use of any vacant spaces that may occur on the sheet, for the north point, area, and title. The plan should be in the centre of the paper, and the level sections underneath. The author prefers where possible, to show the north point as already described, so that the top of the paper represents north and the bottom south, and so forth.

Conventional Signs.—Grass land is coloured green.

Water is coloured prussian blue.

Cultivated land is coloured burnt sienna.

Footpaths, roads, streets, land and gravel are coloured yellow ochre.

Buildings (brick or stone) are coloured crimson lake.

Buildings (wood) are coloured sepia.

Buildings (temporary) are coloured Payne's grey or indian ink.

Some draughtsmen verge each portion of the plan with a narrow band of its respective colour but of a rather darker shade. If well done this is very effective.

Hedges and Ditches as in Fig. 66. Or draw a thin line for

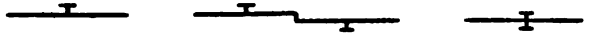


Fig. 66.

Fig. 67.

each edge of the ditch, and sketch in elevation the hedge on whichever side of the ditch it occurs. (Fig. 67.)

The height of the bushes shown should never be more than

$\frac{1}{8}$ inch and should be disconnected. The ditch may be shaded in pale blue and the bushes in dark green.

Fences.—All fences are usually shown on plan by a single line but if it is required to distinguish between the various kinds, this may be done as shown in the two following examples :—

Post and Rail .

Close Paling .

Other conventional signs are—

Parish Boundary .

County Boundary .

Gate . . or

Walls . .

Footpath . .

Cart track . .

Road . . .

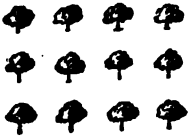
Railway .

Or strong blue line.

Trees

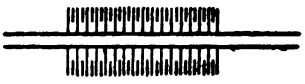
In elevation $\frac{1}{2}$". Their shadow falls to the right.

Orchards

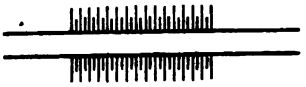


Woods

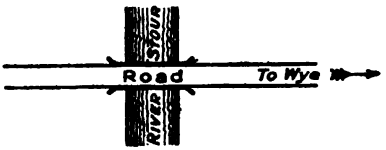
Cutting



Embankment



Bridge



Stile

Manhole

Wherever there is any doubt, names should be written.

Finishing up a Plan.—Any elaborate ornamentation is not to be recommended.

Printing.—Plain upright block printing (see Fig. 68) carefully done and with the letters well spaced is the best to use for titles and the names on different plots ; roman or sloping block for names of roads, and italics for names of adjoining owners and details. (Fig. 69.) Printing is the most difficult part of plan-drawing to acquire, and constant practice is required.

A B C D E F G H I J K L M N O P Q R S
T U V W X Y Z

FIG. 68.

PLAN OF FIELDS
PLAN OF FIELDS
PLAN OF FIELDS

FIG. 69.

Border Line.—There should be a thick border line about an inch from the edge of the sheet. There are many different kinds but Figs. 70 and 71 show two good kinds.

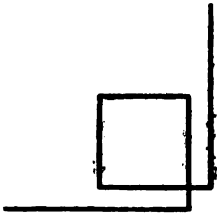


FIG. 70.

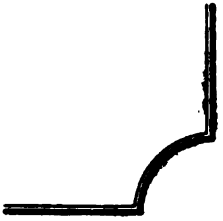


FIG. 71.

North Point.—If any decoration is thought necessary it should consist principally of straight lines.

Methods of Enlarging, Reducing and Copying Plans

Enlarging and Reducing Plans.—1. Re-plot the plan to the scale required.

2. By 'squares' and proportional compasses.

3. By the Pantograph.

4. By the Eidograph.

Of these No. 1 is undoubtedly the best where there is time. No. 2 is very satisfactory, however, and is much adopted in estate offices, where the pantograph and eidograph seldom find a place, but it is not a safe method for enlarging when great accuracy is required.

By Squares and Proportional Compasses.—Take a piece of tracing paper or cloth and rule it with inch or half-inch squares, and place it on the plan to be enlarged or reduced, fastening it securely with drawing pins. Now take a sheet of drawing paper, and on it with a very soft lead pencil rule the same number of squares to the required scale, larger or smaller as the case may be.

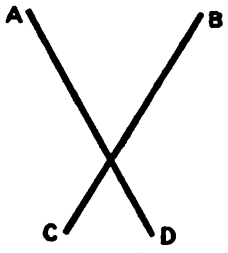


Fig. 72.

The copy is then made by transferring the part included in each square separately. This is done by means of the proportional compasses, which will enable us to fix each point by measuring its horizontal and vertical distance from the corner of a square. The proportional compasses are set to the proportion desired, and the rectangular co-ordinates are measured on the larger squares by the AB end of the compasses, and transferred to the smaller squares by the CD end of the compasses. (Fig. 72.)

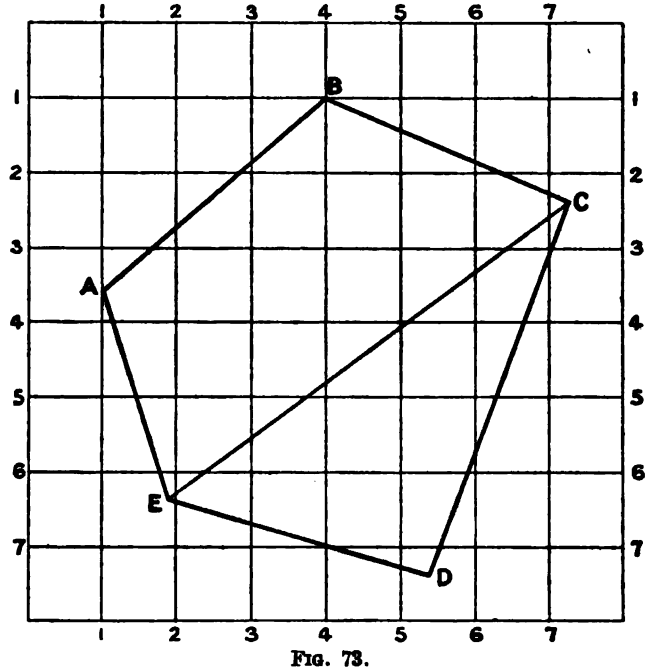


Fig. 73.

Example.—AB, BC, CD, DE; and EC in Fig. 73 represent the fences of two fields: it is required to reduce this plan to the scale of one-half. It should be remembered that when a plan is reduced to half the scale, the area is reduced to one-fourth. Similarly, if the scale is one-third of the original, the area will be one-ninth.

On a piece of tracing paper draw squares as shown in Fig. 73, say, with sides of ½ inch, and place this piece of tracing paper over the plan ABCDE as shown.

Next draw upon a sheet of drawing paper a similar set of squares, but with each side only half the length of the former, i.e. ¼ inch as shown in Fig. 74. Now, if we draw the sides AB, BC, CD, DE, and EC (Fig. 73) in the corresponding squares in Fig. 74, we shall, obviously, have a copy of the plan *ab*, *bc*, *cd*, *de*, and *ec* on half of the scale.

Each point where a fence crosses a square is fixed on the original, as already explained, with the proportional compasses, and transferred to a similar position on the copy. For instance, the point B which is at the intersection of horizontal 1 and vertical 4, in Fig. 73 must occupy the same position in Fig. 74.

By the Pantograph. — The ordinary pantograph will only reduce or enlarge in the few proportions marked upon it, but the **Eidograph** will do so in any proportion. Neither of these is used very much now; their place has been taken by Coradi's precision pantographs. The pantograph is used for copying full size, reducing or enlarging drawings. The original is traced by a point called a tracer, and a pencil point draws the copy in the desired scale according to the setting of the instrument. The old pantographs rested by means of universal casters on the surface of the table. They were awkward to use, and difficult to guide, and their exactitude depended on the condition of the surface of the table, which had to be disproportionately large. Precision pantographs should furnish a perfect reproduction of the original in the desired proportion, and the error should never exceed $\frac{1}{10}$ mm. in any direction, so that the process cannot be carried out as accurately by any other means.

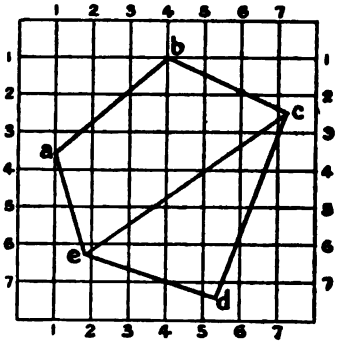


FIG. 74.

Copying Plans.—This may be done by several methods.

1. By re-plotting the plan.
2. By transferring the plan by means of transfer paper.
3. By pricking it off.

To do this place the plan over a clean sheet of drawing paper, fasten with pins to a drawing board, and then prick through the essential points. By joining these points on the clean sheet of drawing paper we obtain an exact copy of the plan, if the original is composed mainly of straight lines. This method is very quick, but should only be used when damage to the original plan does not matter.

4. By making a tracing of the plan on tracing cloth.
5. By the tracing frame, or copying glass.

   Cover the plan to be copied with drawing paper and place it on the pane of glass. The lines of the plan can be seen distinctly through the sheet and so traced. A window pane may be used in a similar manner.
6. By the ferro-prussiate process.

   In this process the lines appear white on a dark blue ground. First trace the plan on good, transparent, clear tracing cloth of a bluish tint, in dense black lines of indian ink. Place the tracing against the glass of the printing frame and the prepared sheet at the back of the tracing. Now expose the frame to light until the prepared sheet attains a deep bluish tint. Then remove the sheet from the frame and thoroughly wash in clear water in a zinc tray till the lines appear white.
7. By photography.

   The 6-inch ordnance sheets are reduced from the 25-inch ordnance sheets by this method.
8. By the pantograph.

A plan can, of course, also be copied by the 'square' method.

The makers give the following instructions and descriptions of their pantographs, which are reproduced here by their kind permission.

I. General Description of the Pantograph

(a) *Pole at the end*

All Coradi pantographs are constructed on the same system, as is shown diagrammatically in Fig. 75.

Four horizontal bars 1, 2, 3, 4 are connected so as to form by means of the vertical axes *a*, *b*, *c*, *d* a movable parallelogram. The axis *d* forms at the same time the pole P, which rests in a frame, and about which the whole instrument turns. Z is the sleeve carrying the pencil point and F the sleeve carrying the tracing point. By means of metallic wires the instrument is suspended at *h* and *h'* to a frame.

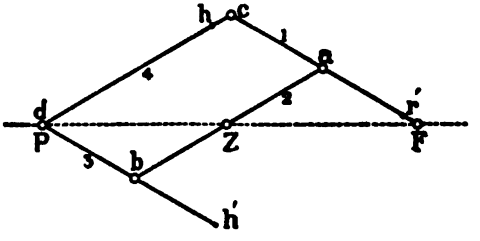


Fig. 75.

At *r'* the instrument rests on the table. The distance of the axis *a* from *b* and the axis *c* from *d* is invariable and exactly equal to the invariable distance of the axis *c* from the tracer F : $ab = cd = c\mathrm{F}$. The distance *c*F determines the size of the pantograph,

which is made in four different lengths, viz.: 600 mm., 720 mm., 840 mm., and 960 mm., the zero for *c*F being at *c*, for *ab* at *b* and for *db* at *d*, i.e. at P. The distances *ac*, *db*, and *b*Z can be varied, but *ac* must always = *bd* = *b*Z. In this hypothesis *ca* : *c*F :: PZ : PF. If O represents the linear magnitudes of the original, R those of the reduction, then R : O = PZ : PF = *ca* : *c*F = *b*Z : *ba*.

As the length *c*F is known, it is only necessary, in order to find for a desired ratio $\frac{R}{O}$ the position x of the axes *a* and *b*, and of the pencil point Z, to multiply this length L by $\frac{R}{O}$.

$$x = \frac{R \cdot L}{O} \quad . \quad . \quad . \quad . \quad (1)$$

For example if it be required to reduce a drawing so that the reduction is to the original as 2 : 3; $\frac{R}{O} = \frac{2}{3}$ and if the pantograph have a length of 840 mm., then $x = \frac{840 \cdot 2}{3} = 560$ mm., the distance *ca* = *db* = *b*Z, to which the axes *a* and *b*, and the pencil point Z have to be set. If the drawing is to be enlarged, the original and reduction change places, i.e. the drawing to be enlarged is placed under Z and the paper on which the enlargement is to be made under F; the tracer is placed in the sleeve Z and the pencil point in the sleeve F; in the above-mentioned equation R in this case represents the original and O the reduction.

Example.—If it be required to reduce a map from the scale 1 : 1000 to the scale 1 : 1500, the ratio $\frac{R}{O} = \frac{1000}{1500} = \frac{2}{3}$, i.e. $x = 560$ mm. as above; or if it be required to enlarge a map from the scale 1 : 1440 to the scale 1 : 960, the reduction R is then treated as the original and the ratio is therefore $\frac{960}{1440} = \frac{2}{3}$, the setting x again 560 mm.; and so on. The system shown in Fig. 75 has proved the best for a steady suspension and adapts itself easily to the unevenness of the surface of the table. Moreover, as the distances *ab*, *cd*, and *c*F are invariable and accurately fixed, once for all, at 600, 720, 840, and 960 mm., and only three variable distances have to be set, great exactitude is obtained.

The table on p. 88 gives the greatest dimensions of a rectangle which can be traced with the point F of a pantograph, without shifting the pole, for the four sizes which are made and for different ratios. The lesser figure gives the dimensions in the direction PF, the greater figure the dimensions in the direction vertical thereto.

(b) *Pole in the Centre*

From the same table, as also from the setting formula $x = \frac{R \cdot L}{O}$, it is seen that the dimension of the greatest rectangle which can

be traced diminishes in the direction PF according as the ratio set approaches 1 : 1, and that if the latter ratio is required, i.e. a copy of the same size as the original, the pencil point and tracer would fall at the same point F, i.e. the reproduction of a drawing in the same size would be impossible. In order, however, to be able

Ratio set according to formula (1) $z = \frac{R.L}{O}$	Length (cF) of Pantograph.			
	60 cm.	72 cm.	84 cm.	96 cm.
	Dimensions of the greatest rectangle which can be traced			
$\frac{1}{10}$ to $\frac{1}{8}$	75 cm. × 75 cm.	90 cm. × 90 cm.	105 cm. × 105 cm.	120 cm. × 120 cm.
$\frac{1}{10}$ to $\frac{1}{6}$	70 cm. × 70 cm.	85 cm. × 85 cm.	100 cm. × 100 cm.	115 cm. × 115 cm.
$\frac{1}{6}$ to $\frac{1}{5}$	65 cm. × 65 cm.	80 cm. × 80 cm.	95 cm. × 95 cm.	108 cm. × 108 cm.
$\frac{1}{5}$	50 cm. × 60 cm.	60 cm. × 72 cm.	70 cm. × 85 cm.	80 cm. × 100 cm.
$\frac{1}{6}$	40 cm. × 60 cm.	48 cm. × 72 cm.	56 cm. × 85 cm.	66 cm. × 100 cm.
$\frac{1}{7}$	35 cm. × 60 cm.	42 cm. × 72 cm.	50 cm. × 85 cm.	56 cm. × 100 cm.
$\frac{1}{8}$	22 cm. × 60 cm.	27 cm. × 72 cm.	30 cm. × 85 cm.	36 cm. × 100 cm.
$\frac{1}{9}$	18 cm. × 60 cm.	22 cm. × 72 cm.	26 cm. × 85 cm.	30 cm. × 100 cm.

to set the instrument at 1 : 1 and to obtain the largest dimensions for the ratios near 1 : 1 for surfaces to be traced in one position of the pole, arrangements have been made in other types of pantographs for the pencil point Z and the pole P also to be exchangeable, i.e. to change places, so that the pole, the turning point of the whole instrument at Z, lies between the tracer F and the pencil point Z —see the diagrammatic illustration in Fig. 76 in which the letters and figures have the same signification as in Fig. 75. Most of the weight of the pantograph is supported by a diagonal tube, kept horizontal at h' by a metallic wire fixed to the frame vertically over the pole P which rests in the frame ; a second wire, the length of which can be varied according to the setting chosen, is suspended at h' to the bar 2 ; at r and r' the instrument rests on the table. Consequently there are two points, besides the pole P, which rests on the table, and as the surface of the latter is rarely sufficiently level and horizontal, the whole instrument must be set up quite horizontally in order to avoid strain. For this purpose screws and if the scale is one-third of the original, the area will be one-ninth.

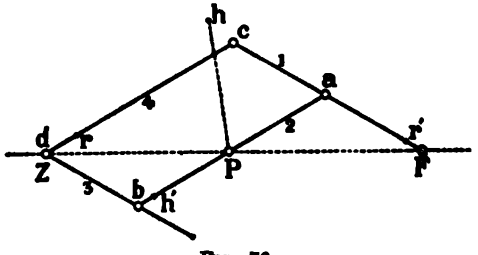


Fig. 76.

box levels are attached to the frame, in order to make the axis P quite vertical, and micrometer screws are fitted at the points of suspension to enable the bars and the supporting tube to be placed horizontally; r and r' are also adjustable in height by screws, in order to allow for the unevenness of the surface of the table. For the purpose of setting to various ratios PZ : PF, the two axes a and b and the pole P are adjusted and ac must always $= bd =$ bP; PZ : PF is then always as $ac : a$F $= bd : a$F $=$ Pb : Pa. As the zero for the division of the bars 1, 2, 3 is at c, d and b respectively, as in Fig. 75, therefore the formula for the setting x of the three variables distances ca, db, and bP is—

$$x = \frac{\text{R} \cdot \text{L}}{(\text{O} + \text{R})} \quad . \quad . \quad . \quad . \quad (2)$$

in which $\frac{\text{O}}{\text{R}}$ represents the linear proportion of the original and reduction.

For example, if it again be required to reduce a map from the scale 1 : 1000 to the scale 1 : 1500, the ratio is $\frac{1000}{1500} = \frac{2}{3}$ and if the pantograph again have a length L 840 mm. the setting $x = \frac{840 \cdot 2}{(2 + 3)}$ $= 336$; or if it be required to enlarge a map from the scale 1 : 1440 to the scale 1 : 960, as the tracer, when enlarging, does not change places with the pencil point the ratio $\frac{1440}{960} = \frac{3}{2}$ is to be taken as the ratio for setting. Therefore $\frac{3 \cdot 840}{(2 + 3)} = 504$ as the setting for a, b, and P.

If the plan which is to be enlarged or reduced is shrunk, so that its indications no longer stand in the original relation to the true values, the pantograph can be set, by a simple calculation, so that the reduction made with same stands in the proper relation to the full values.

1. *Example.*—A plan originally made on the scale 1 : 1000 has shrunk 1 per cent.; 100 mm. of the plan are therefore equal to a length of 101 m. in the full size; the scale of the plan is therefore no longer 1 : 1000 but 1 : 1010. If it be required to reproduce this plan in the scale 1 : 1500, i.e. to reduce it, the ratio R : O is therefore $\frac{1010}{1500}$; in accordance with formula (1) for the pole at the end (Fig. 75) the setting x, when L is 840 mm., is $x = \frac{840 \cdot 101}{150} =$ 565·6 mm. and in accordance with formula (2) with pole in the centre (Fig. 76) $x = \frac{840 \cdot 101}{(101 + 150)} = 338{\cdot}0$ mm.

2. *Example.*—A plan originally drawn in the scale 1 : 1440 has shrunk 1 per cent.; 100 mm. of the plan are therefore equal to 145·44 m. in the full size. The scale of the plan, in consequence of the shrinkage, is 1 : 1454. If it is required to reproduce this plan in the scale 1 : 960, i.e. enlarge it, the setting x in accordance with formula (1) with pole at the end is: $x = \frac{840 \cdot 960}{1454} = 554{\cdot}6$ and in accordance with formula (2) with pole in the centre (Fig. 76) the setting is $x = \frac{1454 \cdot 840}{(1454 + 960)} = 505{\cdot}95$ mm.

The following table gives the greatest dimensions of a rectangle which can be traced with the tracer F of a pantograph of 960, 840, 720, or 600 mm. length, without shifting the pole, when the pole lies between the tracer F and the pencil point Z.

Ratio set according to the formula $s = \frac{B \cdot L}{(B+O)}$	Length (cF) of the Pantograph			
	600 mm.	720 mm.	840 mm.	960 mm.
1 : 1	35 cm. × 55 cm.	42 cm. × 68 cm.	50 cm. × 80 cm.	60 cm. × 90 cm.
2 : 3	40 cm. × 65 cm.	50 cm. × 75 cm.	60 cm. × 90 cm.	72 cm. × 100 cm.
3 : 2	20 cm. × 35 cm.	25 cm. × 45 cm.	35 cm. × 55 cm.	45 cm. × 65 cm.

II. General Rules for using the Pantograph

The table on which the instrument is to be used should be as even as possible, approximately horizontal, and preferably rectangular in shape: the size varies with the size of the pantograph used. The width may be from 0·9 m. to 1·20 m. The length should be about twice the length of bar of the pantograph. Slate or marble table-tops covered with thick smooth linoleum have been found very suitable.

The pantographs of the types I and II are, when put in their cases, set to the ratio $\frac{1}{2}$ (or $\frac{1}{1}$) so that they must always be set to the same ratio before being returned to their cases. The sleeves F and Z, as also P are placed in the middle of the case, the joint C to the right. When taking the instrument out of the case and carrying it to and from same, hold it with the right hand near the joint C at the two bars 1 and 4, the left hand being placed against the joint B at the bars 2 and 3, to avoid bending the bars or straining the joints; for the same reason the instrument should be supported by a book or the like at the points of suspension h and h' when laid on the table, before being suspended. The setting of the pantograph to a determined ratio is effected only after it is suspended and adjusted horizontally, as the sleeves of the bars 1 and 3 can only

be properly adjusted with the whole instrument in a horizontal position. The bars must be carefully protected from bending and always clean, so that the sleeves can be moved easily on same. The points Z and F and their sleeves must always be kept clean and free from oil or dust, so that the points fall freely into the sleeves. When it is necessary to clean the latter a strip of soft cotton-cloth about 4-5 cm. long, twisted at the corner, should be drawn through the sleeve ; the points should be rubbed occasionally with a soft, dry rag.

III. Description of the Pantograph

1. Pantograph type I

For reducing, enlarging, and copying full size.

(a) *Setting with pole in the centre* (Figs. 76 and 77)

The bars 1, 2, 3 and 4 are hard-drawn brass tubes of rectangular cross-section. Their joints move between pointed screws, so that

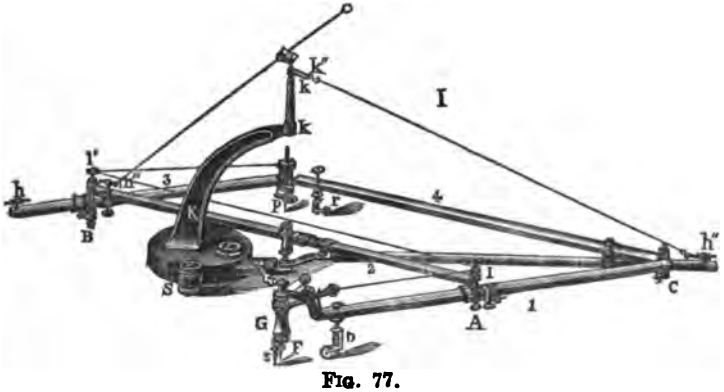


Fig. 77.

very easy working is obtained and any play can be at once removed by their adjustment. On the bars 1 and 3 sleeves are fitted which can be moved easily along their whole length ; to these sleeves the pointed screws for the joints A and B are attached : by adjusting these screws the distance CA and PB can be varied. On the bar 2 is a similar sleeve carrying the guide for the pole pin and enabling its distance from the joint B to be varied ; a shorter sleeve in each case carries the necessary micrometer screw for the fine adjustment. All the sleeves can be fixed to the bars from underneath by the means of set screws ; the screw of the short sleeve is first tightened and, after the instrument is set the screw of the longer sleeve.

The bars 1, 2, and 3 are divided on one side of their upper surface in millimetres, with divisions on the other side for the most usual

ratios. The latter are marked $\frac{1}{10}$ to $\frac{4}{5}$ and $\frac{2}{3}$ to $\frac{1}{1}$ to $\frac{3}{2}$. The figures for the arrangement with pole at the end (Fig. 75) are on the left, those for the arrangement with pole in the centre (Fig. 76) on the right of the respective division. Each sleeve carries a vernier for $\frac{1}{10}$ mm. and an index for setting to the ratio division. The zero of the divisions and of the verniers is so arranged that the latter indicate accurately the distances of the adjustable axis A from C, and B from P or the turning point (pole) of the instrument from the joint B; with the verniers the distances calculated by the formulæ $x = \frac{R \cdot L}{O}$ and $x = \frac{R \cdot L}{(R + O)}$ can be immediately set.

The instrument is principally supported by the frame K, in the foot of which at P (Fig. 80) the pivot bearing of the instrument, a hollow half sphere recessed in a steel cylinder, is fixed. Vertically over the pivot P is the axis piece k', k'', on a crane-like arm, around which the suspending wires turn. This axis piece is taken out when forwarding the instrument and is provided with a hole, through which an ordinary pin or point is passed for screwing same on firmly. The straight line Pk' should be vertical, which is effected by means of the two set screws S, S and the box level; whether the latter is correctly placed, i.e. whether the axis Pk is shown to be truly vertical by the box level, can be easily verified by the supporting tube 1. The fork end of this tube is supported at P, where the ball bearing screws into the steel cylinder, the other end is attached to the suspending bolt at h'' by means of the longest wire and at k'' to the frame, so that the supporting tube can be turned in a horizontal plane almost 360°. The small level accompanying the instrument is now placed in the two positions parallel to the straight line adjoining the set screws S, S and rectangular thereto on the supporting tube, as near as possible the frame, on the same side of the tube. By means of these set screws S, S and the eyelet screw h'' the level can be brought into all three positions for determining if the axis of rotation Pk is quite vertical; the box level should now indicate this; if not, it must be adjusted without shifting the frame, by means of the correcting screws (two draw-screws and two pressure-screws).

If the pantograph is to be used as shown in Fig. 76, i.e. **with pole in the centre,** the frame K is placed on the table so that its foot P is in the centre of the table and the straight line joining the set screws S, S forms with the longitudinal edge of the table an angle of about 45° and the box levels balance. The instrument is now placed on the table, the pole-ball in the sleeve Z on bar 2 is placed in the bearing of the frame and the bolt drawn over it. The supporting tube is pushed through under the caster of bar 4, its fork end placed against the pole cylinder, the other end suspended by means of the longest wire at h'' and at the top eyelet of the frame at k'' and the tube adjusted horizontally, as stated above by means of the eyelet screw h''.

The sleeve on bar 2 carrying the pole pin must now first be set to the ratio at which it is required to work. The wire, provided with one suspension hook only, is attached to the eyelet h''' on bar 2, the clamping piece, with ball recess adjustable on this wire, is placed over the small ball at the top end of the pole axis k and the length of wire adjusted so that bar 2 is approximately horizontal. By means of the screw eyelet h''' on bar 2, the bar is then placed exactly horizontal, then by means of the screw on the caster r, bar 4 is placed horizontal, and likewise bar 1 by means of the screw on the caster r'. By reason of the unavoidable deflection of the bars it is advisable always to place the level in the middle of same. It will then be seen if the axis Pk of the frame is vertical. If the pantograph is correctly suspended and horizontal it will, when guided by the handle G, move easily in all directions.

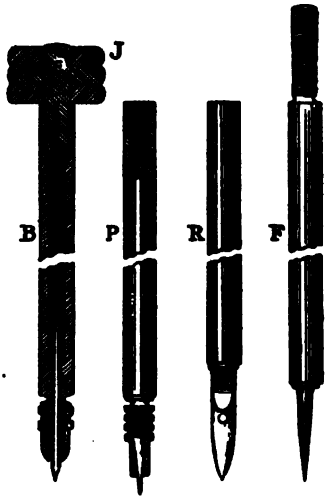


FIG. 78.

According to the ratio set, a smaller or greater part of the weight of the instrument rests on the caster r' of bar 1. So as to obtain for all settings a uniformly easy motion for the exact guiding of the tracer, a regulating device is attached to the caster. A part of the weight rests on the support p (Fig. 79), the other part on the caster r'. If the caster r' alone carried the weight, the motion of the instrument would be too light; if the weight rested on p alone the motion would be too heavy. If the spiral spring is strengthened by screwing up the nut m, the caster r' supports a greater weight and the motion is easier; if the nut m is unscrewed the spiral spring is slackened and the motion becomes heavier, as p then carries a greater load; in this way the desired heavier or lighter motion can be easily obtained.

In Fig. 78 the necessary points for the pantograph are illustrated—viz., tracer point F, pencil point B, pricking point P, and the ink point R. (The latter is only supplied to order.) All the shafts of the points are exactly cylindrical, of uniform diameter and fit properly in the three sleeves F, Z, and P. Faber leads of 1·9 mm. diameter fit the **pencil holders.** The point of the lead should be as central as possible, so that, if the pencil resting on the paper is turned in its sleeve Z, a dot only is made on the paper and not a circle. The pin t can be put in at the top with one or more loading discs, to obtain finer or thicker lines. The pin t, with loading weights, can also be placed on the **pricker** P. The

latter carries a screwed protecting sleeve, which can be adjusted so that the point does not project more than it will enter the paper; when the pricker is not in use this sleeve is screwed out to cover the point, and protect it from injury. The tracer F is screwed at the top to take the nut with spring sleeve shown in Fig. 79. This serves to keep the tracer off the paper when the reduction is only to be pricked, in which case the tracer can be quickly moved from one angle of the original drawing to the other. By pressing with the index finger on the tracer the point of the latter can be pressed down at the precise place to obtain a very accurate setting. When tracing the lines of the original, if the drawing is to be reproduced in pencil or ink, it is, however, better to screw up the spring sleeve so that the tracer rests on the prop *c*, placed so that the tracer point travels just clear of the paper.

When using the ink point, the lines can be made in ink at once: the pen is so ground that it enables uniform fine lines to be made in all directions (also transversely to the split opening of the pen): the indian ink must, however, be very thin and the stem of the pen kept very clean, so that it falls freely in the sleeve without requiring to be loaded.

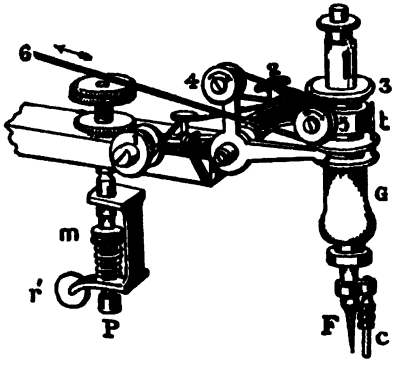


FIG. 79.

The handle G (see Fig. 79) embracing the tracer sleeve, serves both for guiding the instrument and raising and lowering the pencil (pricker or pen). It can be moved vertically; if the handle is drawn down the pencil also sinks on the paper; when using the pricker the handle is pulled down quickly which imparts a free falling movement to the pricker. A spiral spring keeps the handle raised, so that, when at rest, the pencil is also raised. The arrangement and action of the releasing cord is to be seen from Fig. 79; the releasing lever turning around a horizontal axis engages its front horizontal arm in the groove of the handle G, the back arm is drawn down by a spiral spring, which on the one side is attached to the tracer bar and on the other side to a part adjustable on the arm. If the latter is pushed towards the pivot of the lever, the action of the spring becomes weaker. This position is used when working with the pencil or ink point. In order to strengthen the action of this spring, to enable it to draw the pricking point out of the paper, the point of suspension is removed from the turning axis (pivot) of the releasing lever. As when using the pencil the hand gets overtired, through constantly pulling down the handle during the tracing, the vertical pin *t* is fitted to the handle G. By turning the handle, when

in its lowest position, this pin can be brought under the yoke of the bar 1, so that the handle remains down, i.e. the pencil remains on the paper. The releasing cord is carried from the reel 1 round the fixing screw at the back arm of the releasing lever between the two discs at the clamping screw 2, round the nut 3, over the pulleys 4 and 5, in the direction of the arrow. Thence it is carried over the pulley 1 (Fig. 77) at hinge A, then over the pulley 1′ at hinge B. Care is to be taken that the cord is carried over these two pulleys in the same direction ⌒, otherwise the cord will become lengthened or shortened by the movement of the instrument during work. From the hinge B the cord is carried to the pulley on the pencil sleeve (P, Fig. 77) and fastened to the clamping arm under the sleeve of the pencil point. By winding or unwinding the reel 1 the cord is given such a length that, when the handle G is raised, the pencil point is also raised as much as possible, and, when the handle G is lowered, the pencil point rests on the paper and the cord is slack. This length of cord is maintained by tightening the clamping screw 2 on the tracer bar yoke. The instrument is now ready for use.

(b) *Setting with Pole at the end* (Figs. 75 and 80)

If the pantograph is to be used for ratios under $\frac{2}{3}$, it is advisable to set it up with the pole at the end. (See Fig. 75.) For this purpose the frame is placed at the end of the table and the axis P*k*′ is made

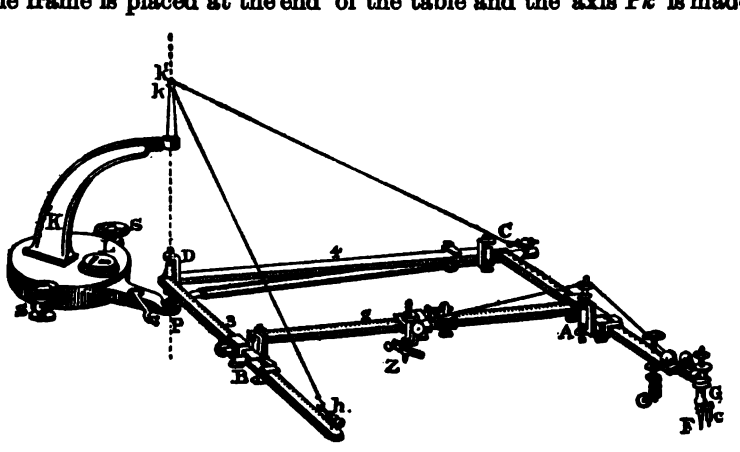


FIG. 80.

vertical by means of the screws S, S and the box level. The pole-ball pin is taken out of the sleeve Z on bar 2, placed in the sleeve at the hinge P, secured with the nut, placed in the bearing at the foot P, and the bolt drawn over it. The longest wire is attached to the supporting tube and to the top eyelet of the frame at *k*′ : the shortest wire is attached at *h* to the bar 3 and to the frame at *k*′, the bars 3 and 4 are adjusted horizontally by means of the eyelet screws *h*

and h' on the supporting tube and bar 1 by means of the screw on the caster r', whereby bar 2 is also brought into a horizontal position. For pantographs of more than 60 cm. length of bar the frame must be loaded with additional weights, in order to obtain an absolutely steady position of the axis Pk on the table. With instruments of 72 cm. length one such weight is supplied, with those of 84 cm. and 96 cm. length two, which are pushed from the back over the curved stand K and placed one on top of the other. After these weights are applied, the vertical position of Pk, and the horizontal position of the bars 3 and 4 must again be examined and, if necessary, adjusted. The pencil point is now placed in the sleeve Z on bar 2 and connected with the releasing mechanism by fastening the clamping lever of the releasing cord to the bottom of the pencil holder and leading the cord over the pulley on the pencil point sleeve, over the pulley 1 at hinge A, and thence to the releasing lever in the same way as described under (*a*).

For enlarging with this setting of the instrument (Fig. 75) the

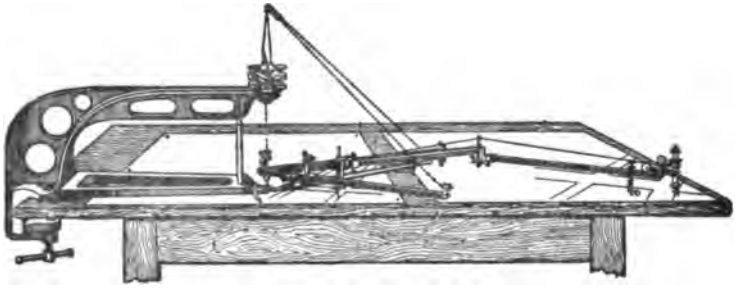


Fig. 81.

tracer is placed in the sleeve Z on bar 2 and the original drawing also placed there. The pencil point is placed in the sleeve F on bar 1, underneath which the clamping arm of the releasing cord is fastened to the pencil point. From here the cord is now led over the pulley 5 on the tracer bar (Fig. 79) over the pulley at hinge A and thence, as when reducing, back again over the pulley 5 to the releasing lever. In the case of big enlargements it is advisable only to set the angles of the rectilinear figures as exactly as possible, to reproduce them on the enlargement and then join them up with lines. In the case of curved figures, points are also marked at suitable distances and joined up by freehand on the enlargement. When using the pantograph for this purpose, i.e. for enlarging by pricking, it is advisable to leave the tracer in the sleeve F and use it as a pricking point by removing its prop and screwing down the nut with the spring sleeve till the tracer point is 3–4 mm. clear of the paper: the prop *c* (Fig. 79) is now brought to the pricking point in the sleeve Z which is used as the tracer, after removing the protecting

sleeve. The moving of the instrument is also effected with the handle G.

(c) *Frame with Suspended Foot.*

When making large reductions $\frac{1}{5}$ to $\frac{1}{10}$, the foot P of the frame, or the whole of the latter rests entirely on the paper on which the reduction is drawn, so that it is somewhat difficult to get the parallel sides of the original and of the reduction to coincide. The new frame has therefore been made with a suspended foot. This foot stands about 5 mm. above the surface of the table and reaches 40 cm. over the table, from the edge, so that the drawing paper can be easily pushed under the foot, until the pencil point stands at the same angles of the reduction to which the tracer is set on the original.

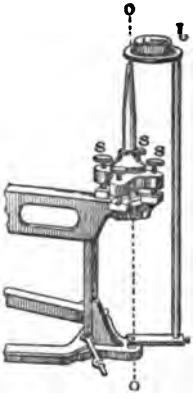


FIG. 82.

The above illustration (Fig. 81) shows the application of this new frame and its connection to the pantograph. The head, with the four set screws S (Fig. 82), is put in the case separately. For connecting same with the frame the ends of the four screws are placed in the grooves in the top of the frame, the connecting pin, fixed thereto by a cord, is pushed through, and the screw S slightly tightened. In order to make the axis *o o* (corresponding to P*k* in Fig. 80) vertical, a box level with connecting rod accompanies the instrument, the application of which can be seen distinctly from Fig. 82; the box level is set by means of the four screws S and the correct position of the same is examined and corrected in the same way as indicated under (*a*) for the axis P*k*. When using this new frame for the setting with pole in the centre, the areas which can be traced are smaller than in the case of the ordinary frame. This new frame is only supplied to special order.

CHAPTER V

THE SUBDIVISION OF AREAS

BEFORE engaging in the work of measuring distances in the field, for the purpose of subdividing areas, setting out allotments or building plots, a survey of the land should be made, or a tracing of the area to be divided taken from the Ordnance Map. On this plan or tracing the subdivision should first be carefully set out, and the actual measurements in the field made from it.

When measuring along a straight line to stake out new fences, the measurement should always be a continuous one, as it will be found that a mistake can easily be made if each piece or frontage be measured separately. As has been carefully pointed out in Chapter II these measurements must be horizontal.

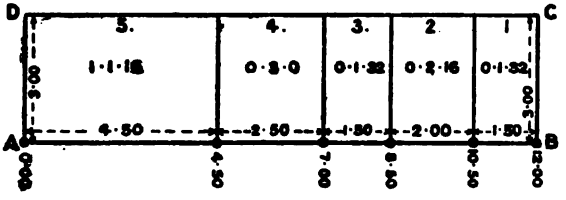


FIG. 83.

It will serve as a check if the line measured closes on a station in the survey. Fig. 83 shows a tracing of the plots set out in the office for use in the field.

AB is 12 chains long from station A on the survey to station B. The lengths of each added together are, of course, equal to 12 chains, and the areas of each plot added together are equal to the area of the whole rectangle ABCD. If the rectangular plot of land ABCD be for sale in plots, and it be required to measure off plot No. 1 which has been sold, the remainder should afterwards be measured, and the two areas should together equal the whole area ABCD.

The stakes used for marking out allotments or plots of land should be, say, $2\frac{1}{2}$ inches square and 15 inches long. These should be put in nearly level with the ground. If nails be

driven into the stakes at the top, so that they project perpendicularly say half an inch, and a cord be stretched from nail to nail, the ground, if pasture, may be nicked out along this line to indicate the exact position of the new fence.

When dividing lands for purposes of sale or otherwise, it is always advisable, when the division is to be made between arable and pasture, to see that the ditch is in the arable field.

Building plots should be measured in feet and inches, and the frontage and depth figured on the plan.

The measurement of land under crops and woods should not include hedges or ditches, when it is made for the purpose of payment of labour.

When an agent has the management of a home farm, he should make a plan showing the exact positions of all permanent objects such as trees, gate-posts, &c. By this means he will be enabled

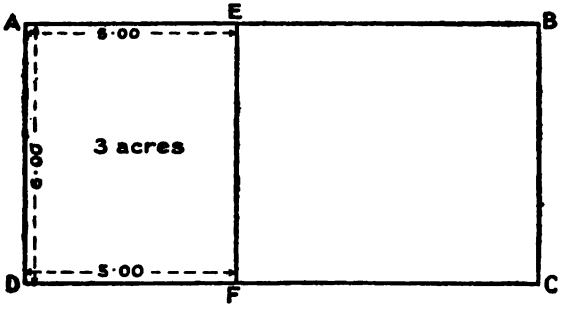


FIG. 84.

to ascertain quickly the areas under the different crops by measuring along the fences from such fixed points. The cropping may then be shown on the plan after computation in the office by aid of the scale.

The Ordnance Map $\frac{1}{1500}$ may be used for making this plan by taking a tracing of it on good tracing cloth.

To lay off a plot of land of a given size, from a rectangular field.—If we divide the area required to be set off by the length it gives us the breadth, and *vice versa*.

Example.—Let ABCD (Fig. 84) be the given field: it is required to lay off a plot of land equal to 3 acres. The side AD is 6 chains. Divide the area (3 acres) by this side and we get the length of the sides to be measured off along AB and DC.

6 chains = 600 links.

and 3 acres = 300,000 square links.

$\therefore$ 300,000 ÷ 600 = 500 links, as the length required.

A line joining the points E and F will give the required area, viz. 3 *acres*.

To lay off a plot of land of a given size, from an irregular field. —(a) *When one fence is crooked and the other two are straight and parallel.*

Let ABCD (Fig. 85) be the given field: it is required to lay off 3 acres.

Join AB, and work out the area included between AB and the crooked fence.

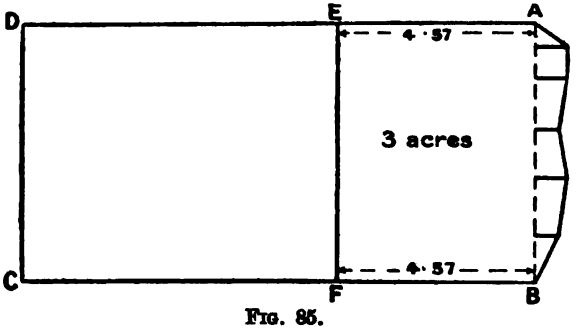


FIG. 85.

Suppose AB measures 6 chains and the area of the offsetted piece = 25,800 square links.

Area required = 300,000 square links
Area of offsetted piece = 25,800 ,,
Difference = 274,200 ,,

Now divide this difference by 600 (length of AB in links) and

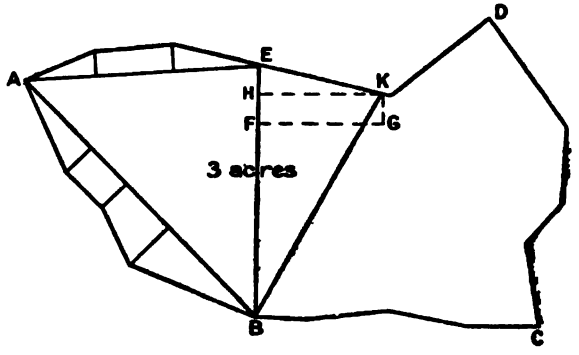


FIG. 86.

we get the length of the sides to be measured off along BC and AD, i.e. 274200 ÷ 600 = 457 links, as the length required to be measured from the points A and B.

A line joining the points E and F will give the required area —namely, 3 *acres*.

(b) *When all the sides of the field are crooked.*—Let ABCD

(Fig. 86) be the given field: it is required to lay off 3 acres by a straight fence running from B towards AD.

Draw the lines AB, BE, and EA. Find out the area of the triangle ABE and the offsetted pieces between AE and the crooked fence and AB and the crooked fence.

The triangle AEB = 162,250 square links
Offsetted pieces = 53,970 „ „
216,220 = area cut off by EB

Now, 3 acres = 300,000 square links
Area already set off = 216,220 „ „
Difference = 83,780 to be added

EB measures 590 links. Then 83780 ÷ 590 = 142 links. Multiply 142 by 2 and we get the perpendicular of the triangle to be added —namely, 284. Now on EB at any point erect the perpendicular

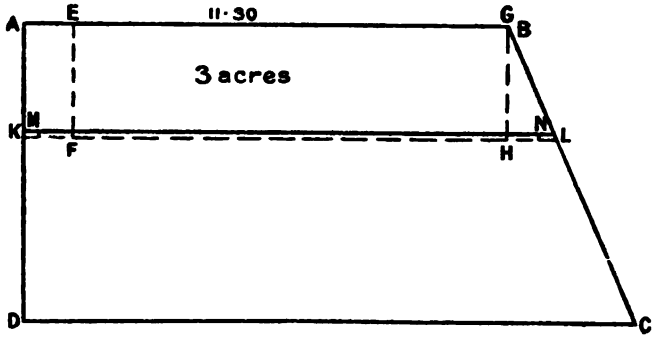


FIG. 87.

FG 284 links: set off GK perpendicular to FG until it meets the fence at K. Join BK. Then the line BK sets off an area equal to 3 *acres*.

To lay off any given quantity of land from a field bounded by straight fences, by a line parallel to one of the straight fences.— Let ABCD be the given field, Fig. 87, it is required to lay off 3 acres by a straight fence running parallel to AB which measures 11·30 chains.

3 acres = 300,000 square links
300000 ÷ 1130 = 265½ links (approx.)

Then 265½ links is the length of the perpendiculars EF, GH to be set up on AB at either end. Set off these perpendiculars and measure the line KL which equals 12·50 chains.

The figure ABLK is a trapezoid and its area equals—

$$\frac{(1130 + 1250) \times 265\frac{1}{2}}{2} = 315{,}945 \text{ square links}$$

The area set out is consequently too much by 15,945 square links (315945 — 300000).

Then 15945 ÷ 1250 = 13 links (approx.), the perpendicular distance to be measured at either end of KL between K and A, because KL cuts off an area larger than the required quantity.

Draw the line MN through the extremities of these perpendiculars and MN cuts off the required quantity—namely, 3 *acres*.

To lay out a given quantity of land in the form of a rectangle, so that the length has a given proportion to the breadth.—A rectangular plot of land 3 acres in extent, the sides of which are in the proportion of 1 and 6, is required to be divided into 20 equal plots and frontages to the long side. What is the frontage of each ?

If we multiply the two terms of the proportion together, and divide the product into the given area, then the square root of the quotient, multiplied separately by the terms of the proportion, will give the required length and breadth of the sides.

Example.

$$6 \times 1 = 6)\overline{300{,}000} \text{ given area in square links,}$$
$$\overline{50{,}000}$$

The square root of 50,000 = 223·6

∴ the breadth = 223·6 × 1 links

and the length = 223·6 × 6 links

∴ the long side = 1341·6 links

Therefore the frontage of each plot is 1341·6 ÷ 20 = 67 links, or say 44 feet (approx.).

To divide a rectangiar piece of land among a given number of purchasers, by fences parallel to one of its sides.—Let ABCD be

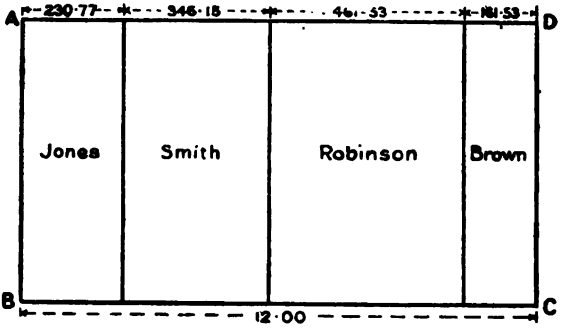


Fig. 88.

the rectangular piece of ground (Fig. 88) which is 12 chains long and 6·60 chains wide. It is required to divide it amongst four purchasers who paid for their shares as follows: Jones, £100; Smith, £150; Robinson £200; Brown, £70.

Total amount paid = £100 + 150 + 200 + 70 = £520.

Then 520 : 100 : : 1200 : Width of Jones' property = 230·77 links
520 : 150 : : 1200 : „ „ Smith's „ = 346·15 „
520 : 200 : : 1200 : „ „ Robinson's „ = 461·54 „
520 : 70 : : 1200 : „ „ Brown's „ = 161·54 „
1200·00

Measure off the widths thus found along AD and BC and join the points. The field will then be divided as required.

To cut off a given quantity of land from a triangle, by a line parallel to one of its sides.—Let ABC be the given triangle (Fig. 89). AB = 1200 links, AC = 800 links, and BC = 600 links. It is required to cut off 2 acres by the line DE parallel to AB.

The area of the triangle is found from the three sides as explained in Chapter I.

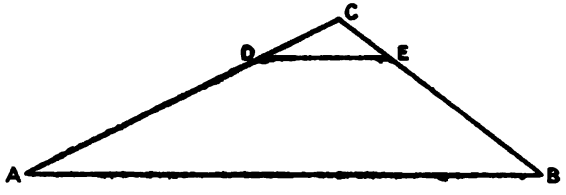


Fig. 89.

Area of ABC = 213,307 square links.
The area to be cut off = 200,000 „ „
∴ the difference = 13,307 „ „ = the area of the triangle DCE.

Now the areas of triangles are as the squares of their like sides.

Therefore the area of the triangle ABC : the area of the triangle DCE : : $AC^2 : DC^2$.

∴ 213,307 : 13,307 : : 800^2 : 39,926 (approx.)

The square root of 39,926 = 200 (approx.).
800 − 200 = 600 links = AD.

Again by similar triangles—

AC : BC : : AD : BE
∴ 800 : 600 : : 600 : 450
∴ BE = 450

Now measure off along AC from A the distance AD = 600 links and along BC from B the distance BE = 450 links.

Join DE and ADEB is cut off, equal to two acres, from the triangular field as required.

In this way a triangle may be divided into any number of parts by lines parallel to any one of its sides.

To divide a triangular field in certain given proportions so that each person may have the use of a well situated at one of its corners. —Let ABC be the given field (Fig. 90) : it is required to divide it among four persons. Let the given proportion be as the numbers 2, 3, 4, 5, and the well be at C. Let AB = 2800 links.

Then as $2 + 3 + 4 + 5 =$ $14 : 2 :: 2800 : AD = 400$
$14 : 3 :: 2800 : DE = 600$
$14 : 4 :: 2800 : EF = 800$
$14 : 5 :: 2800 : FB = 1000$
2800

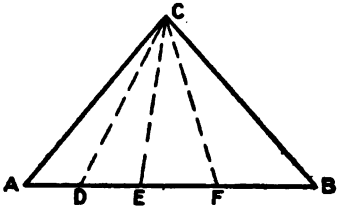


Fig. 90.

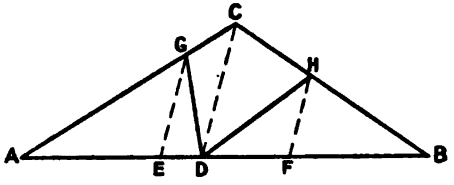


Fig. 91.

Therefore 400, 600, 800, and 1000 are the proportions of the line AB which belong to each person. Draw lines from D, E, F to C, and the field is divided as required.

To divide a triangular field into any number of parts, by fences from a point in one of its sides.—Let ABC be the given field (Fig. 91) and D the given point on AB. Let it be required to divide it into three equal parts. Trisect AB in the points E and F. Join DC. Draw EG and FH parallel to DC meeting AC and BC in G and H.

Join DG and DH, and these lines will divide the field as required.

CHAPTER VI

LEVELLING

Levelling is the art of determining and representing the inequalities in the surface of any portion of the earth. Whereas surveying may be described as the *horizontal* measurement of the ground, levelling may be taken as the *vertical* measurement.

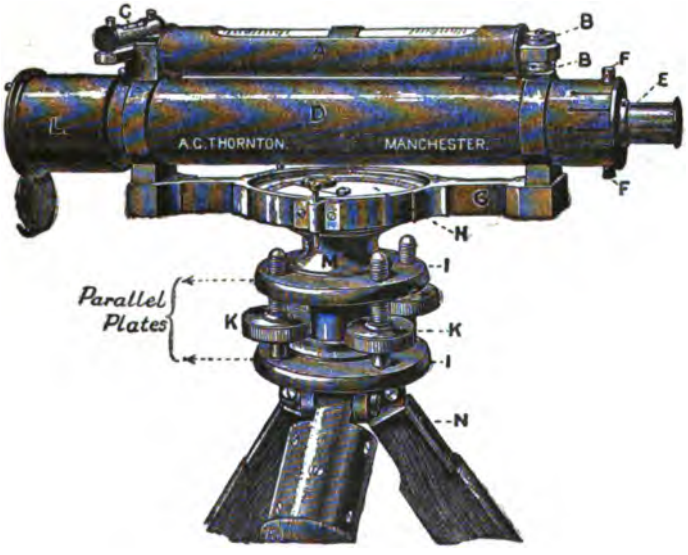


FIG. 92.

DUMPY LEVEL.	12"	14"	16"
Weight of Levels . . .	7 to 8 lb.	9 to 10 lb.	10 to 11 lb.
Weight of Tripod . . .	8 lb.	10½ lb.	10½ lb.

The subject of levelling does not cover much ground in a practical way, and can only be learnt in the field, but nevertheless there is a considerable amount of book-work to be grasped.

The method employed by surveyors is that of obtaining a level line (i.e. a line parallel to the surface of still water), and measuring from this the distances vertically downwards to the various positions of which the level is required.

FIG. 93.

For this purpose the Dumpy Level (Fig. 92) is required. It consists of A the longitudinal or principal bubble tube, to which is attached a telescope D, whose central axis is parallel to the run of the bubble.

B, B are the capstan adjusting screws to the bubble tube; and C the small transverse bubble tube and its adjusting screws; E the eyepiece; F, F the screws for adjusting the diaphragm; G the support for compass and telescope; H the compass; I, I the parallel plates; K, K the milled-headed parallel plate screws; L the sun shade; M the conical axis terminating in a universal ball-and-socket joint; N the tripod on which the instrument is set up.

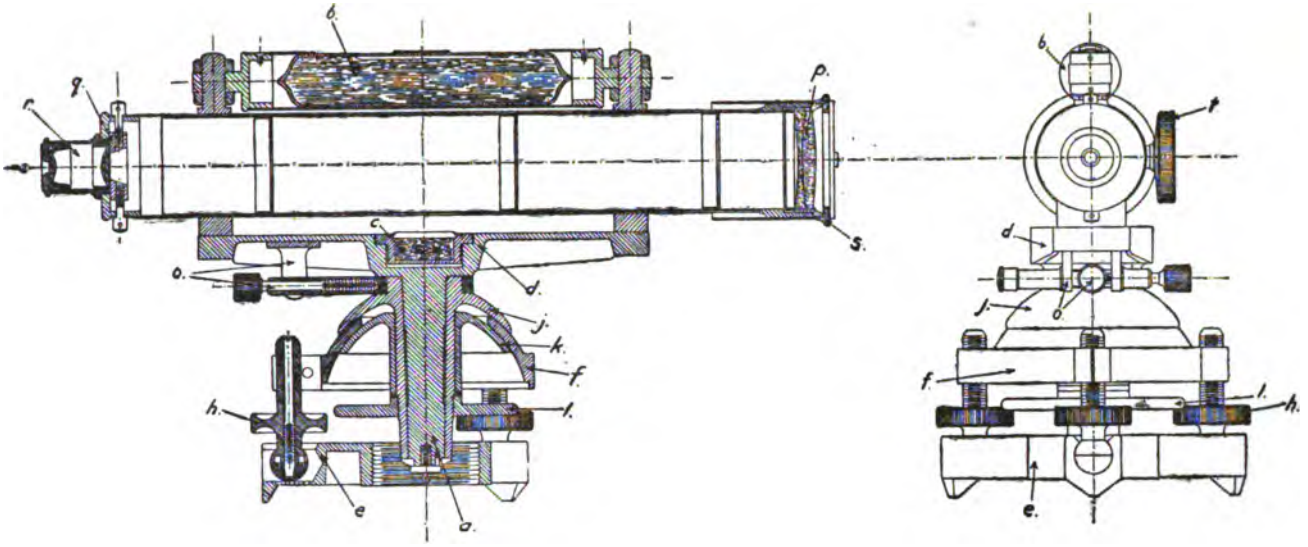
By looking through the telescope to a staff, usually graduated in feet and hundredths of a foot, the distance downwards from the level plane to the spot upon which the staff is held may be read.

Fig. 93 represents one of the best patterns of levelling staves, the Sopwith pattern; 14 feet in length; cost about 45*s*.

Fig. 94 is a sectional drawing of Messrs. Thornton's latest pattern of Dumpy Level, showing the different parts. This pattern has three screws for levelling the instrument, but another arrangement is made in which four screws are used as shown in Fig. 92. The former is called the *Tribrach Construction*, and the latter the *Parallel Plate System*. The tribrach construction gives greater rigidity.

With the parallel plate system there is a tendency for the screws to jam, and if they are worked when tight they very soon destroy the surface of the plates and thread.

The **diaphragm** contains the cross-lines or other means of showing on the staff what figures are to be read. Fig. 95 (p. 108) gives the various types of diaphragm fittings.



References

(*a*) Axis	(*e*) Bottom tribrach	(*k*) Bottom friction plate	(*q*) Diaphragm
(*b*) Bubble	(*f*) Top tribrach	(*l*) Clamp screw	(*r*) Eyepiece
(*c*) Circular bubble	(*h*) Plate screw	(*o*) Clamp & tangent	(*s*) Ray shade
(*d*) Stage with axis combined	(*j*) Top friction plate	(*p*) Object glass	(*t*) Pinion screw

FIG. 94.—ENGINEER'S DUMPY LEVEL

With quick setting joint and improved three-screw adjustment.

Another pattern of level called the Y level is shown in Fig. 96. This is the oldest form of surveyor's level and is so called because its telescope is supported in Y-shaped bearings. Two collars C, C are soldered round the telescope exactly fitting the Y's. These collars are so made that the telescope may be turned end for end in the Y's without changing the direction of its axis in reversing it. The standards are fixed firmly upon the limb by capstan screws B, B. Two pins fix the telescope securely in the Y's. The telescope is free to revolve on its axis, so that perfect adjustment may be made in any direction. The bubble tube L is fixed under the telescope by a joint at one end and

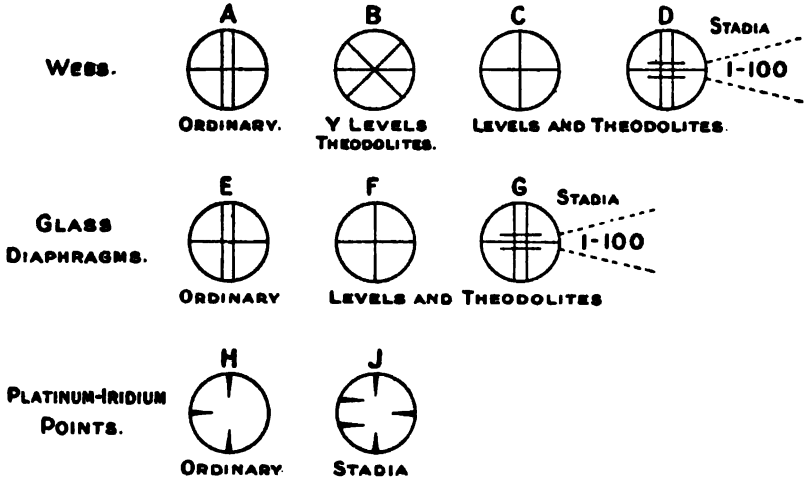


FIG. 96.

a pair of capstan screws N at the other to raise or depress it for adjustment. K is a clamping screw which tightens the collar round the conical axis so that the telescope can be fixed in any required direction; while T is a tangent or slow-motion screw enabling exact adjustment of the telescope to be made upon the staff when the instrument is clamped by K. P, P are two of the three foot-screws for levelling the instrument, showing tribrach system. X, X are the capstan screws for adjusting the diaphragm.

Advantages of the Dumpy Level over the Y Level.—The Dumpy Level was invented by William Gravatt. Its name is derived from its dumpy appearance, due to the short focal length of the telescope.

The correct measurement of a level of any dimensions is the

length from the inside of the object glass to the stop, i.e. the solar focus of the O.G. A 12-inch dumpy should read 0·01 foot on a Sopwith staff at 5 chains with a webbed or glass diaphragm, and a 14-inch dumpy should read 0·01 foot at 10 chains.

The addition of a transverse bubble is a great help, as it enables the instrument to be set up approximately level without turning the telescope several times in two directions at right angles to each other, thereby saving much time.

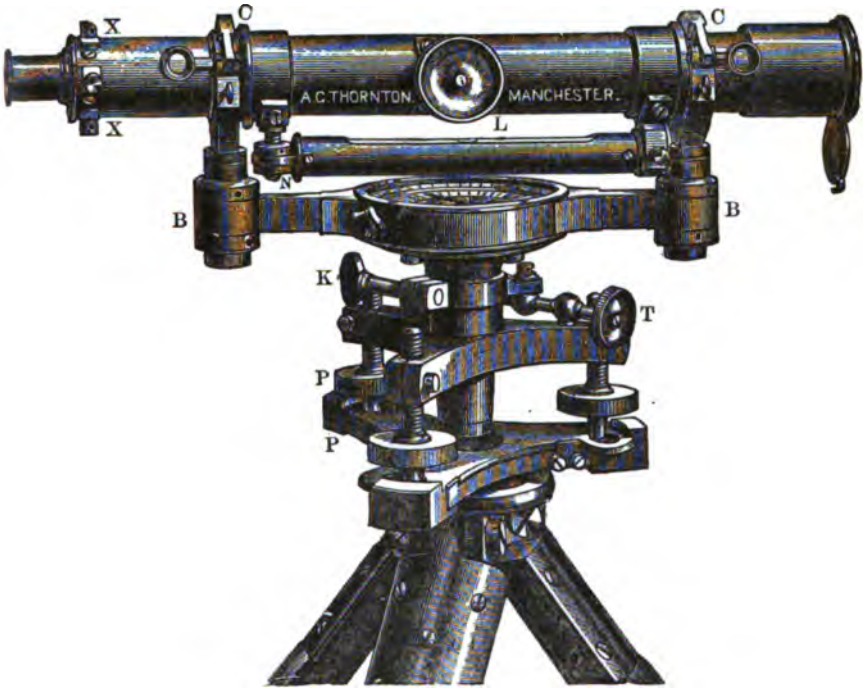


Fig. 96.

Its advantages may be summed up as follows :—

1. The telescope is of shorter focal length.
2. The object glass is larger, thereby admitting sufficient light to allow of a much greater magnifying power in the eyepiece.
3. More compact, convenient, and rigid.
4. Easy to adjust, and rarely requiring re-adjustment when once put in adjustment.

Fig. 97 is a sectional drawing of Messrs. Thornton's Improved pattern Y level.

There are several variations of the afore-described levels and of these Cushing's Reversible Level is a very useful pattern. It is like the Dumpy in construction, except that its telescope is of improved form possessing the necessary adjustment of the Y level. The ends of the tube form stout socket collars which are exactly alike, and are ground to fit either the objective or the eye piece end of the telescope so that these parts may be reversed, the one for the other. The end also rotates in its fitting. By this means adjustments may be made as for the Y level.

Curvature and Refraction.—In taking long sights with the level two natural phenomena must be taken into consideration. The

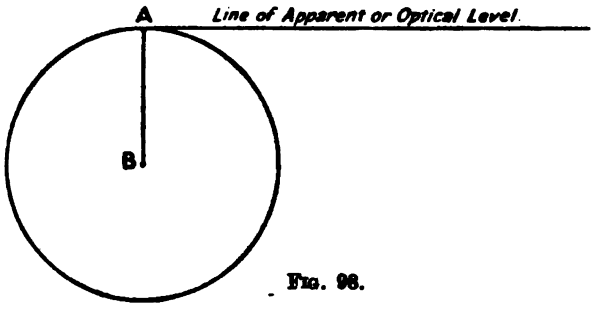


Fig. 98.

fact that the earth is an oblate spheroid makes it necessary for us to make an allowance for what is called *curvature*; and the

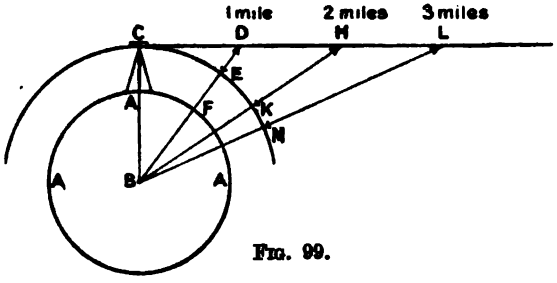


Fig. 99.

variation of the density of the atmosphere requires an allowance to be made for what is termed *refraction*.

Practical levelling is the determination of horizontal lines which are not level lines. A really level line is one which at all points is equidistant from the centre of the earth. A level is the surface of still water.

A sight as taken with a level to a staff is an *apparent* or *optical level*, and is a tangent to the earth extended in space. (See Fig. 98.)

It will be seen from this diagram that a horizontal line (the apparent level) cannot be a level line, because the point at which it is a tangent to the earth's surface must be nearer to the centre of the earth than any other point in it.

Now we want to find out for practice what is the difference between the *apparent level* and the *true level.* (See Fig. 99.) Let AAA represent the earth's circumference, CD a horizontal line, the line of sight of the telescope, which is parallel to the earth's tangent at A.

Now A and F and C and E are on the same level, but obviously D and E are not.

D appears to be the level of the point E, as seen through the telescope at C. CD is the apparent or optical level and CE is the true level. The difference between the apparent and true is therefore ED. From which it will be seen that *curvature causes an apparent depression,* and its correction must therefore be deducted. It is necessary to determine what this correction is. The square of the length of any measured distance in miles divided by the earth's mean diameter (i.e. the average between the Polar diameter and the diameter taken at the Equator) will give the amount of depression to be allowed.

Example.—The correction for one mile is $\frac{1^2}{7913}$, 7913 being approximately the mean diameter of the earth in miles.

$$\frac{1^2}{7913}\text{ mile} = 0{\cdot}667\text{ feet} = 8{\cdot}004\text{ inches} = (\text{say})\ \frac{2}{3}\text{ feet.}$$

Therefore 8 inches may be taken as the correction per mile, but it varies as *the square of the distance.* It will be seen on looking at Fig. 99 that the longer the sight the greater the allowance to be made in proportion. For 1 mile it is ED, for 2 miles KH, for 3 miles ML.

∴ The correction for 1 mile = 8 inches × 1
" " " 2 miles = 8 " × 2^2
" " " 3 miles = 8 " × 3^2

or

The correction for 1 mile in feet = $\frac{2}{3} \times 1 = \frac{2}{3}$ foot.
" " " 2 miles " = $\frac{2}{3} \times 2^2 = 2\frac{2}{3}$ feet.
" " " 3 miles " = $\frac{2}{3} \times 3^2 = 6$ "

Refraction is 'the term generally applied to a change of direction impressed upon rays of light traversing a medium, the density of which is not uniform, e.g. the atmosphere.'

Terrestrial refraction is that refraction which makes terrestrial objects appear to be raised higher than they are in reality, due to the air being denser near the surface than at a higher elevation. Its refractive power increases as its density, and the correction

consequently varies, but is generally taken as *one-seventh of the correction for curvature.*

We have seen that curvature causes an apparent depression, and refraction an apparent elevation, therefore the correction for the latter must be *deducted* from that of the former.

It is more convenient, however, to make the total correction for both at the same time.

To ascertain the total correction for curvature and refraction. — (Distance in miles)^2 × 0·577 = correction in feet and decimals of a foot.

Example.—1. A sight taken with a level to a staff 80 chains off gave a reading of 10·64.

$$\therefore\ 1 \times 0{\cdot}577 = 0{\cdot}577$$
$$10{\cdot}64 - 0{\cdot}577 = 10{\cdot}063, \text{ correct reading on staff}$$

2. Supposing, without making any correction, the height above base were 150·61, what should be the correct height above base?

$$\text{H.A.B.} = 150{\cdot}61$$
$$\text{The correction} = \underline{\ 0{\cdot}577}$$
$$\therefore\ \text{Correct H.A.B.} = 151{\cdot}187$$

3. Find the difference in level between A and B. The distance is 80 chains. The level is set up at A and the staff held at B. A sight to the staff gives a reading of 12·62. What is the difference in level between A and B?

Reading of staff		12·62
Height of Instrument . .	= 4·75	
Correction for Curvature and Refraction	= 0·577	
	5·327	5·32
	Difference of Level =	7·30

Simple Levelling consists of finding the difference in level of two spots. To do this set up the instrument on the tripod, halfway between the two positions of which the difference in level is required, by extending the legs of the tripod until the bubble is nearly in the centre of its run in the tube. (Fig. 103, p. 114.) The legs should be firmly pressed upon the ground, and when this has been done the instrument should be perfectly stable and free from shake of every kind. It is assumed that the level is in adjustment: its adjustments are explained at the end of this chapter. Now place the telescope over a pair of screws (K, K in Fig. 92) as shown in Fig. 100 if it has parallel plates, or as in Fig. 101 if on the tribrach

system (Fig. 96). Place the thumb and first finger of each hand on the screws and turn them at the same time with thumbs going both inwards or both outwards (the bubble will follow the direction of the left thumb) and bring the bubble into the centre of its run. Next place the telescope over the other pair of screws, or other screw, as the case may be, and again level the bubble. Do this in two opposite positions again, so that this time the eyepiece is in the position occupied last time by the object-glass and *vice versa*. The bubble should now remain in the centre of its run during a complete revolution on its axis, if in adjustment.

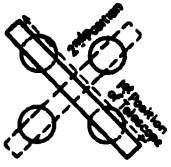


FIG. 100.

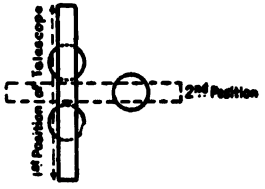


FIG. 101.

The instrument being level direct the telescope on to the staff held at A, and with the web in the diaphragm properly focussed on to the staff take the reading, say 1·32.

To read the staff. — The large figures on the left of the staff (see Fig. 93) represent feet, and do not register until they are cut quite at the top. It will be observed that most level telescopes invert, and the staff will appear to be upside down; this does not cause any inconvenience after a few readings have been taken.

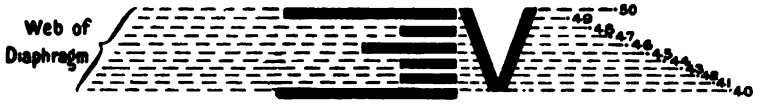


FIG. 102.

The figures on the right-hand side indicate tenths and do not register until they are intersected exactly at their top. The divisions between the tenths represent hundredths and do not register until the intersection is exactly at their top or base. (See Fig. 102.)

The reading 1·32 referred to above is shown in Fig. 93. It will be noticed that in order to save confusion the even tenths are not marked on the staff. The intersection exactly at the base of the odd numbers gives the reading of the even numbers. See 0·60 and 1·80 in Fig. 93 and 0·40 in Fig. 102.

Having taken the reading on the staff in the first position at A (Fig. 103), next place the staff in the second position at B, and take the reading which is (say) 1·90. (See Fig. 93.)

The difference, then, in level is 1·90 — 1·32 = 0·58. The point A is therefore 0·58 feet higher than the point B. The *higher* the reading on the staff the greater the *fall*, as will be seen from Fig. 103.

Compound Levelling.—So far we have only considered the method by which the difference in level of any two points may be found. In practice we usually require the levels of several points in a continuous line and obtain them by what is called compound

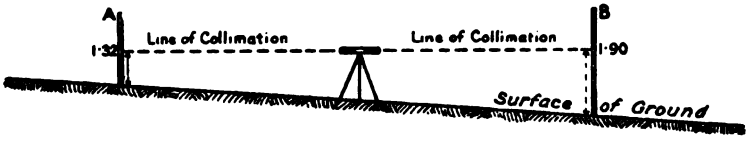


FIG. 103.

levelling. The principle is, however, exactly the same as already described.

Let AL in Fig. 104 represent a section through a portion of the surface of the ground. It is required to take sufficient levels to enable us accurately to plot the section.

Set up the instrument between A and B as shown, and take a reading to the staff held on A and also to the staff held on B. Supposing it is impossible to see with the instrument in its present position as far as the next point C, we must set it up again in such

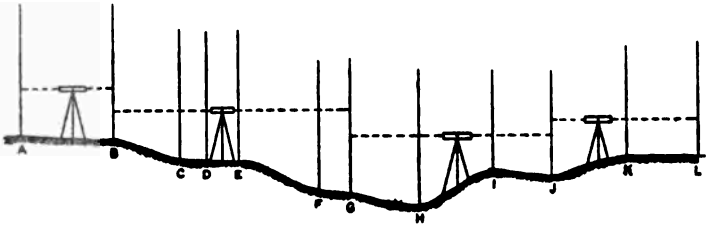


FIG. 104.

a position that B and C can be seen. Let us set it up as shown between D and E, whence the points B, C, D, E, F, and G (say) can be seen. Now with the staff still held on B take a reading with the instrument in its new position : also readings at C, D, E, F and G. We now have the relative levels of C, &c., compared with that of A. In a similar manner the rest of the section may be completed by setting up the instrument as shown in the diagram. A very slight error at the *change points* (i.e. when we move the instrument into a fresh position) would become a large one at the end of a long section. From what has been described it will be

seen that there is no check upon the accuracy of the work, and *all surveying work must be properly checked.*

The usual way to check the work is to commence taking the levels on some spot whose height is known and to finish it on some spot of which the level, relative to that on which we started is known. When it is impossible to find such spots, the practice is to commence levelling at A (Fig. 104) and continue to L, taking the heights of the intermediate points B, C, D, E, &c., and then to continue the work in the opposite direction back again from L to A, taking as long sights as possible. The result should be the same as the difference in level of A and L as first obtained. These levels, from end to start over again, are termed *Check, Running, or Flying Levels.* In any short section, say 40 chains, the error should not exceed 0·05, and increases as the square root of the distance in miles—e.g. permissible error for 3 miles = $0{\cdot}1\sqrt{3}$ feet.

Instead of starting exactly at the commencement of the section A, it is usual to start on some well-defined point such as a gate-post, wall, mile-stone, stump of a tree, or any permanent object, which is called a *Bench Mark.* The staff is held on this and the reading booked in the level book. In checking the section flying levels can be taken back on to this B.M. (Bench Mark).

Datum is some standard of measurement to which all other measurements are referred. It is an imaginary line parallel to the horizon, and also to the Line of Collimation.

Collimation.—The Line of Collimation is the line of sight through the eyepiece of the level at the point where the cross-webs intersect and out through the centre of the object glass to the staff. (See Fig. 103.)

The Datum for Great Britain (Ordnance Bench Mark or O.B.M.) is the mean sea level (M.S.L.) at Liverpool. Ordnance Bench Marks are placed at numerous points all over the country and are shown thus :—

Fig. 105.

The positions and heights of these Bench Marks above Datum are shown on the ordnance maps. The use of Bench Marks is, as already stated, for checking levels, for changing the direction of the line of levels from a point, or to pick up and continue the levels from the point at which they were left on the previous day. When running a long line of levels it is as well to leave frequent Bench Marks, say at every 20 chains, so that in case of the accidental removal of the staff, or cessation of work due to weather, &c., it is easy to return to the last B.M. and resume the work from that point.

The Datum for Ireland passes through a point on Poolbeg Lighthouse, Dublin Bay, at low-water mark of spring tides.

Another Bench Mark used is in the Thames Valley. It is known as *Trinity High Water* (T.H.W.). It is the level of the lower edge of a stone fixed in the face of the river wall upon the

east side of the Hermitage entrance to the London Docks. T.H.W. is taken as 12·48 feet above O.B.M.

Trial Levels are levels taken at long distances apart in order to find out the feasibility of a scheme of works such as a railway, &c. The levels are taken at points which can be readily identified on the map.

Entering Levels in the Field Book.—By entering the readings taken with the instrument in their proper places and correctly reducing them, all the required allowances for the different positions of the instrument are made. The levels of the different points are reduced to heights given in feet and decimals above some assumed level base called the Datum, from which they are plotted.

The following is the mode of procedure in entering and reducing the levels :—

Enter the first reading that is taken after each setting up of the instrument in the column headed '*Back Sight*,' and the last reading taken in each one position of the instrument in the column headed '*Fore Sight*.' All other readings must be put in the column headed '*Intermediate*.' In starting the work the first reading, taken on a Bench Mark (10·30), is entered in the *Back Sight* column. (See Fig. 106.)

FIELD BOOK

Back Sight. (B.S.)	Intermediate. (Inter.)	Fore Sight. (F.S.)	Rise. (R.)	Fall. (F.)	Height above Base or Reduced Level. (R.L.)	Distance. (Dist.)	Remarks.
10·30					20·00	Datum	20 feet below B.M. on Gate-post.
	7·60					0·00	Commencement of Section.
	6·40					1·00	
	5·10					2·00	
	5·90					3·00	
	8·30					4·00	
	9·11					5·00	
	9·09					6·00	
11·17		10·56				7·00	
	12·13					8·00	
	15·16					9·00	
	14·19					10·00	
	7·18					10·50	
	6·04					11·00	
8·06		7·09				11·50	
11·13		10·11				12·00	End of Section.
		12·10				—	B.M. on top of mile-stone.

FIG. 106.

In the remarks column a full description of the Bench Mark should be given, and it is a good plan to make a sketch of it so that there may be no doubt as to its position. If the height of the position be known or assumed it should be entered in the column headed '*Height above Base*' or '*Reduced Level.*' The height of any point above any Datum is called the Reduced Level (R.L.) or sometimes Height above Base (H.A.B.). For convenience' sake it is usual to take any imaginary datum below the earth's surface some even number of feet, such as (say) 20 below the first station, and reduce all levels to this. In choosing this imaginary datum we select one sufficiently large to prevent any levels coming below it. This avoids contrary signs (+ and —) in the calculation and facilitates plotting. To enter the next reading, which is an intermediate (7·60), place this in the *Intermediate* column, and the distance along the chain line in the *Distance* column (1·00 chains), with any descriptive remarks required in the *Remarks* column. The same is done with the rest of the Intermediates 6·40, 5·10, &c.

The last reading we take before moving the instrument is 10·56, this is consequently a *Fore Sight* and must be entered in the F.S. column, with its distance along the chain line (7·00) in the *Distance* column. We shall now move the instrument, set it up in its new position and take the reading of the same spot again. That is to say the staff holder at 7 chains will hold the staff on the same spot until it has been read again by the surveyor with the instrument in its new position. By this means we keep each line of collimation relative to the preceding one. This reading (11·17) being the first taken after setting up the instrument will be a *Back Sight*, and must, therefore, be entered in the B.S. column. As the position of the staff is the same as that of the F.S. just taken it would seem best to enter it on the same line, though some surveyors prefer it to be entered on the next line, so as to keep each line of collimation separate. The remaining levels are taken and entered in a similar way until the whole are as shown in Fig. 106.

To Reduce the Levels, i.e. to calculate the H.A.B. of each spot.

Rise and Fall Method

Take the difference between the first and second readings, and if the first be the larger enter the difference in the *Rise* column: thus 10·30 − 7·60 = 2·70: enter 2·70 in the *Rise* column on the same line as the 7·60. (See Fig. 107, p. 118.)

The difference between the 7·60 and the next reading 6·40 is 1·20, which is also a rise and must be entered in the *Rise* column. The difference between 6·40 and the next reading 5·10 is 1·30, to be entered in the *Rise* column. The difference between 5·10 and 5·90 is 0·80 to be entered in the *Fall* column, because the next reading 5·90 is *greater* than the preceding one. The difference

between 5·90 and 8·30 is 2·40, to be entered in the *Fall* column. The difference between 8·30 and 9·11 is 0·81 to be entered in the *Fall* column. The difference between 9·11 and 9·09 is 0·02, to be entered in the *Rise* column. The difference between 9·09 and 10·56 is 1·47 to be entered in the *Fall* column. We have now done with the figures 10·56 and the first line of collimation from 10·30 to 10·56 is complete. Now start with the figures 11·17 and proceed as before until we reach the figures 7·09 and the second line of collimation from 11·17 to 7·09 is complete. Next take the figures 8·06 and 10·11; the difference is 2·05 to be entered in the *Fall* column, and the third line of collimation is complete. Lastly take the figures 11·13 and 12·10; the difference is 0·97 to be entered in the *Fall* column, and the fourth and last line of collimation is complete.

RISE AND FALL METHOD

B.S.	Inter.	F.S.	R.	F.	R.L.	Dist.	Remarks.
10·30					20·00	Datum	20 feet below B.M. on Gate-post.
	7·60		2·70		22·70	0·00	Commencement of Section on Peg.
	6·40		1·20		23·90	1·00	On Peg.
	5·10		1·30		25·20	2·00	„
	5·90			0·80	24·40	3·00	„
	8·30			2·40	22·00	4·00	„
	9·11			0·81	21·19	5·00	„
	9·09		0·02		21·21	6·00	„
11·17		10·56		1·47	19·74	7·00	„
	12·13			0·96	18·78	8·00	„
	15·16			3·03	15·75	9·00	„
	14·19		0·97		16·72	10·00	„
	7·18		7·01		23·73	10·50	„
	6·04		1·14		24·87	11·00	„
8·06		7·09		1·05	23·82	11·50	„
11·13		10·11		2·05	21·77	12·00	End of Section, on Peg.
		12·10		0·97	20·80	—	B.M. on top of mile-stone.
40·66		39·86	14·34	13·54	20·80		
39·86			13·54		20·00		
0·80			0·80		0·80		

FIG. 107.

To check the accuracy of this part of the work. Add up the B.S. and the F.S. and deduct the one total from the other. Thus 40·66 — 39·86 = 0·80. *Do the same with the Rise and Fall columns, and the difference in the one case must be the same as in the other, thus* 14·34 — 13·54 = 0·80.

The next thing to do is to make up the R.L. column. This is done by adding each rise to or deducting each fall from the R.L. of the preceding point. Thus the first point being 20·00, the second, as there is a rise of 2·70, will be 22·70, and the next, as there is a further rise of 1·20 will be 23·90. The next point will be 25·20 as there is another rise of 1·30. The next point, however, will be 24·40 because there is a fall from the last point of 0·80, and so on.

To check the accuracy of this part of the work. Having completed the R.L. column, deduct the last R.L. from the first R.L. or vice versa and the difference thus formed must be the same as the difference between the totals of the B.S. and F.S. and also the same as the difference between the totals of the Rise and Fall columns.

The field book being now complete, it remains for us to plot a section on paper from the field notes. As there is a very great disproportion between the horizontal lengths and vertical heights, it would be impracticable to prepare a long section so that the vertical measurements could be easily read with the same scale. Consequently it is the practice to choose two different scales, one for the horizontal and one for the vertical measurements. The horizontal scale is generally the same as that to which the plan, if any, is plotted, say 1, 2, 3 chains to the inch.

The vertical measurements are plotted to a much larger scale, say 10, 20, 30 feet to one inch. For a long section a much smaller horizontal scale may be used : a proportion of (say) anything from 50 to 100 to 1. It will be seen that in using the scale of 1, 2, 3, &c. chains to the inch the *same side of the scale* may be employed for plotting the vertical heights of 10, 20, 30, &c., feet to the inch—*care being taken not to use the feet side of the scale.*

It is a very easy matter to prepare the section. Take a piece of drawing paper and carefully pin it to the drawing board. Draw on it with a T square in pencil the datum line. The datum line is plotted on paper as a perfectly straight line, notwithstanding that it partakes of the form of a curve. Mark off on this the horizontal distances with a pricker, and figure them in from the notes in the distance column. Erect, with a set square working on the T square, at each of these points perpendiculars in pencil, slightly beyond the height of their actual requirement. Figure in all the vertical heights, taken from the R.L. column, and prick them off on the perpendiculars by means of the scale. Now join these points by a straight line. If the perpendiculars are likely to be of an unreasonable length deduct some constant round number from each and make a note on the section base line that it is so many feet above datum. Fig. 108 (p. 120) shows a correct plotting of the levels given in Fig. 107.

The perpendiculars beginning at 1 chain and ending at 11·50 may be inked in in red, also all figures, but the rest may be black.

If the work be checked by levelling with flying levels back to

the starting point, then the R.L. of A as found a second time (see Fig. 109) is the same as was entered at first. It will also be noticed that in checking the book the totals of the B.S. and F.S. are the same, also the totals of the rises and falls. In plotting from such a level book the check levels are, of course, disregarded. It very seldom occurs that the levels work out as exactly as is shown here, and an error within the amount already mentioned may be neglected.

The following are the principal points to be attended to in order to secure accuracy in levelling :—

1. Equality and moderate length of back- and fore-sights. By placing the instrument midway between the B.S. and F.S. errors due to curvature and refraction and of adjustment of the instrument are eliminated. The limit of length of sight from the instrument to the staff should be 660 feet. At this distance the combined error of curvature and refraction is 0·009 foot ($\frac{1}{8} \times \frac{1}{8} \times 0{\cdot}577$) which

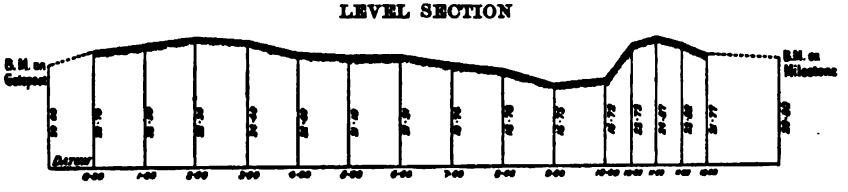


FIG. 108.

may be neglected. Such a distance as this is seldom read, so that the ordinary sights will be well within the mark. Beginners are tempted to take too long sights and it is as well to limit them to (say) 3 chains. It will be seen from this that in practice curvature and refraction may be disregarded : in fact they need only be taken into consideration when taking such sights as are explained under the notes on curvature and refraction.

2. Accurate temporary and permanent adjustment of the instrument.

3. The staff should be held *vertical* by the staff-holder.

4. Careful reading of the staff.

5. Careful setting up of the instrument so as to be free from shake.

6. Care that the staff is on solid ground, especially at the change points.

It is a good plan to set up the instrument so that, if it is a three-screw, one arm of the tribrach (or if a 4-screw, a pair of screws) is exactly under the telescope when taking readings. Then the bubble can always be brought to the centre of its run when reading B.S. and F.S., which is *a very important point.*

If it is found necessary to carry forward the work in the level

book from page to page, the last intermediate should be put into the F.S. column and carried on to the B.S. column on the next page.

LEVEL SECTION

B.S.	Inter.	F.S.	R.	F.	R.L.	Dist.	Remarks.
0·75					60·00A	00	B.M. 60 on Finger-post.
1·54		13·34		12·59	47·41	47	
	0·82		0·72		48·13	58	
	10·45			9·63	38·50	70	
1·02		11·68		1·23	37·27	100	
	9·68			8·66	28·61	36	
	8·42		1·26		29·87	57	
0·98		7·63	0·79		30·66	200	
2·48		12·30		11·32	19·34	21	
	10·30			8·32	11·02	35	
	12·75			1·95	9·07	42	
11·16		6·43	6·32		15·39	79	
12·75		1·10	10·06		25·45	300	
12·30		1·16	11·59		37·04	25	
12·00		1·25	11·05		48·09	60	
		0·09	11·91		60·00	90	Reservoir Outlet
54·98		54·98	53·70	53·70			

FIG. 109.

Collimation Method.—Besides the rise and fall method of keeping the level book there is another known as the *Collimation* method.

COLLIMATION METHOD

B.S.	Inter.	F.S.	Height of Instrument.	R.L.	Dist.	Remarks.
6·14			92·30	86·16	Chains	B.M.
	8·20		,,	84·10	0·00	Commencement of Section.
	9·06		,,	83·24	1·00	
	12·32		,,	70·98	2·00	
		10·18	,,	82·12	3·00	
7·81			89·93			
	6·22		,,	83·71	4·00	
	4·31		,,	85·62	5·00	
	2·00		,,	87·93	6·00	
	1·10		,,	88·83	7·00	
		4·86	,,	85·07	8·00	

FIG. 110.

Fig. 110 gives a few levels entered in this form of book. The first back-sight is added to the reduced level of this point. This gives

the reduced level of the line of collimation of the instrument, which is entered in the *Height of Instrument* column. The readings of the successive points are deducted from this H.I. and give the reduced levels of the several points. For instance, the reduced level of the first intermediate is 92·30 − 8·20 = 84·10, and so forth. When the F.S. has been read, the instrument is set up in its new position as explained before. The new B.S. is read and added to the last reduced level; this gives the H.I. at its second setting. Proceed as before.

To check this form of book, add up the back-sights, and to this total add the R.L. of the starting point. From this subtract the sum of the fore-sights. The remainder is the last reduced level.

Example.—Sum of B.S. = 13·95
First R.L. = 86·16
100·11
Sum of F.S. = 15·04
85·07 = Last R.L.

Also the difference between the total B.S. and total F.S. should equal the difference between the first and last R.L.'s.

Example. 15·04 − 13·95 = 1·09
86·16 − 85·07 = 1·09

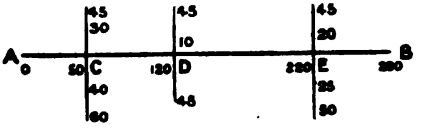


FIG. 111.

Comparison of Rise and Fall and Collimation Methods.—The collimation method saves much labour in the reducing of the intermediates. In the Rise and Fall method there is a check on the intermediates, because any error in the reducing of an intermediate affects all the levels coming after it. In the Collimation method a wrongly reduced intermediate does not affect any other levels. There is, of course, no check on the reading of the staff by either method. Though the Rise and Fall method is that most usual in practice, there is little doubt that the Collimation is as good, if not better.

Cross Sections.—When constructing a road or railway and the ground slopes transversely, transverse levels are required, wherever the surface is uneven and irregular, besides the centre line of levels, in order to calculate the amount of excavation and embankment.

These cross-sectional lines should be set off at right angles with the centre line by means of the optical square. Fig. 111 shows a plan of the longitudinal section with cross-sections at the required intervals. The longitudinal section is taken along the line in the ordinary way already shown, and cross-sections are taken at the points C, D, and E, the distances at which the levels were taken being shown.

The levels of the cross-section may be taken separately or in conjunction with the longitudinal section.

The following (Fig. 112) is a *Form of level book for cross-section levelling* :—

B.S.	Inter.	F.S.	H.I.	R.L.	Distance.			Remarks.
					Left.	Centre.	Right.	
6·14			56·14	50·00		0·00		A
	4·10			52·04		0·50		C
	3·12			53·02	30	0·50		
	4·80			51·34	45	0·50		
	5·20			50·94		0·50	40	
	6·00			50·14		0·50	60	
		7·00		49·14		1·20		D
8·14			57·28			1·20		
	6·20			51·08	10	1·20		
	4·10			53·18	45	1·20		
	7·12			50·16		1·20	45	
		9·16		48·12		2·20		E
						&c.		

Fig. 112.

The level of the ground on the section line at 0·50 is 52·04
" " " " at 30 to the left of 0·50 " 53·02
" " " " 45 " " " " 51·34
" " " " 40 " right " " 50·94
" " " " 60 " " " " 50·14
" " " " 1·20 .. .. .. " 49·14
" " " " 10 " left " 1·20 " 51·08
" " " " 45 " " " " 53·18
" " " " 45 " right " " 50·16
" " " " 2·20 .. .. .. " 48·12

Each cross-section should be plotted separately. Instead of taking the levels of the cross-section with the level, the angle of slope may be taken with the clinometer as explained before, and the angles plotted on the cross-sections by a protractor. The above form of level book is very useful for taking what are called spot levels—that is, levels at numerous different spots. In this

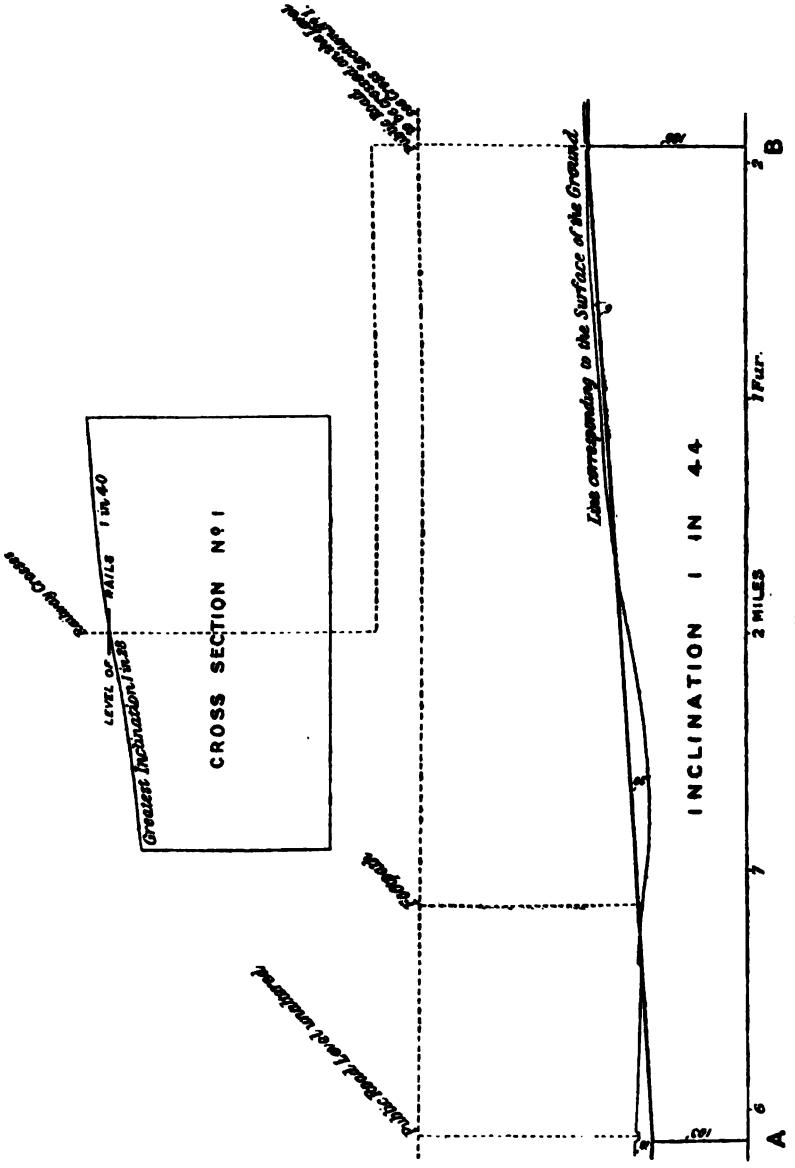

CROSS SECTION Nº 1
INCLINATION 1 IN 44
Line corresponding to the Surface of the Ground
Public Road Level when finished
Footpath
Public Road Level when finished
A
B
2 MILES
1 Fur.

FIG. 113.

case a central line is pegged out at convenient intervals and at each of these intervals cross-sections at right angles are also pegged out as required. Levelling is then proceeded with in the ordinary way by reading as many of the pegs as possible with one setting up of the instrument, then moving the instrument and proceeding as before. The position of each peg is marked on the plan with its letter or number, and each peg is marked to correspond.

Fig. 113 shows a section and cross-section plotted as it should be shown.

Gradients.—A gradient is the ratio of the perpendicular to the horizontal distance. It is generally expressed as a fraction, $\frac{1}{20}$ or 1 in 20; meaning that the difference of level in a horizontal distance of 20 feet is 1 foot.

To find the rate of inclination of a gradient.—Find the difference in height above the datum at the beginning and end of the gradient, and divide this into the *horizontal* length of the gradient.

Example (Fig. 113).

The distance from A to B is 42 chains. The H.A.B. at A is 103 and at B 166: difference = 63 feet. 42 chains = 2772 feet = horizontal length of gradient.

$$2772 \div 63 = 44 = \text{a rise of 1 in 44.}$$

$$\therefore \text{ The gradient is } \tfrac{1}{44} \text{ or 1 in 44.}$$

An inclination of 1 in 20 is the steepest for wheeled vehicles drawn by horses that is practicable for any distance. For short distances such as a quarter of a mile 1 in 16 is permissible, and even 1 in 8 in exceptional places for (say) 50 feet.

By the *angle of slope* is meant the number of degrees formed by the slope and the horizontal.

Example (Fig. 114).

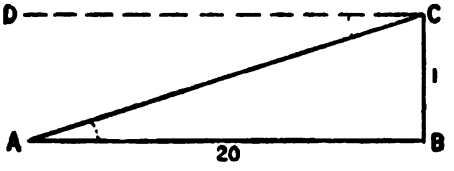


FIG. 114.

ACD = the angle of slope. $\frac{CB}{AB}$ = the gradient.

Gradient = tangent of angle of slope.

The gradient may be calculated from the angle of slope, and the angle of slope from the gradient. (See chapter on Trigonometry.)

Computation of Earth-work.—When the gradient of a road or railway has been decided upon, and the '*formation level*' (shown by the thick black line in Fig. 113) has been drawn on the section in such a way that the amount of earth to be removed in the cuttings as nearly as possible equals the amount required for the embankments, the next step is to calculate the cubic contents of the cuttings and embankments. It is of great importance that the required embankments should never exceed in cubic contents the quantity of the cuttings for obvious reasons; rather should it be slightly the other way.

To obtain the cubic contents.—First divide the quantities of the cuttings and embankments, between the formation level and the ground level on the section, into triangles and trapezoids, as dictated by the undulations of the surface line. Next it is necessary to consider the '*slopes*' or '*batters*' of the cuttings and embankments—1½ to 1 for the former (i.e. 1½ horizontal to 1 perpendicular) and 2 to 1 for the latter may be considered as an average. Suppose the cubic contents of a triangular portion of cutting, such as ABC in Fig. 114, are required to be worked out. Let the slope of the cutting in this instance be 1½ to 1, the height 20 feet, the length 500 feet, and the width 30 feet. The Prismoidal Formula (p. 4, No. 5) must be used.

Calculation

Height =	20	Mean Height =	10
Slope =	1·5	Slope =	1·5
	30		15
Bottom of cutting or width =	30	Bottom of cutting =	30
	60		45
Height =	20	Mean height =	10
Area of larger end =	1200	Middle area =	450
			4
		4 times middle area =	1800
		Area of larger end =	1200
			3000
		Length =	500
			6 | 1500000
		Cubic contents in feet =	250000

250000 ÷ 27 = 9259 cubic yards.

Boning Rods.—These are pieces of wood in the shape of T squares, of exactly the same length, by means of which foremen

of works are enabled to work to levels which have been taken by the surveyor. In Fig. 115 let A, B, C be three pegs which have been put in at a certain level. If the foreman places three boning rods upon these pegs and sights along the top of them, held transversely to a boning rod at D, when the four boning rods are seen exactly level at the top all four spots are on the same level. Or, again,

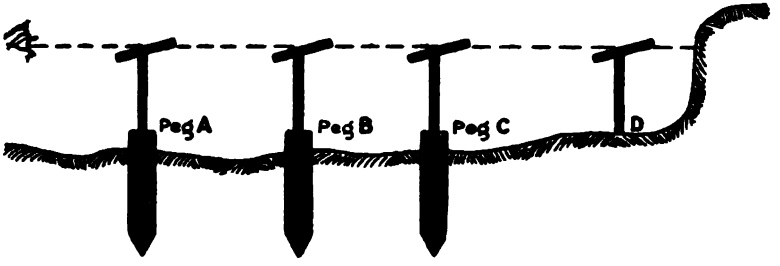


Fig. 115.

if the pegs A, B, C are on a certain gradient, and D be sighted as before, then the spot D will also be on this gradient.

The boning rods are usually 3 feet long, and the cross-piece 15 inches. It is a good plan to have the first B.R. as shown in Fig. 116, with the top edge painted white, and the last as shown in Fig. 117 with the two ends painted black. When setting out curved lines, the cross-piece may be made longer. In setting out

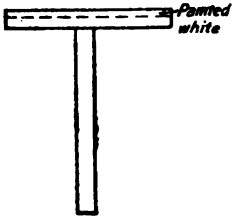


Fig. 116.

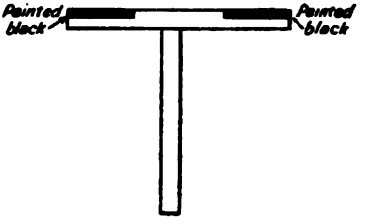


Fig. 117.

the gradient of drains '*sight rails*' are fixed at each end of the inclination, as shown in Fig. 118. They consist of two uprights driven into the ground on either side of the manhole, with a cross-piece nailed to the uprights at a given level above the invert. The invert is the bottom of the channel pipe in the manhole. To the ordinary boning rod another piece of wood is attached so that it is made the same length as the sight-rail above the invert. There,

if the boning rod is held at any point between the two sight rails, the proper gradient is arrived at. (See Fig. 118.)

To Level across a Wall.—It may occur sometimes that the line of levels is intercepted by a wall, during the operation of levelling. If it is inconvenient to level round the wall by a circuitous route, the difficulty may be overcome in the following manner :—

On approaching the wall take a *Fore Sight* to the staff held at the foot of the wall, and book it as usual. Let us suppose the wall to be 13 feet high. There is consequently a rise of 13 feet. The height of the wall is ascertained by measuring it

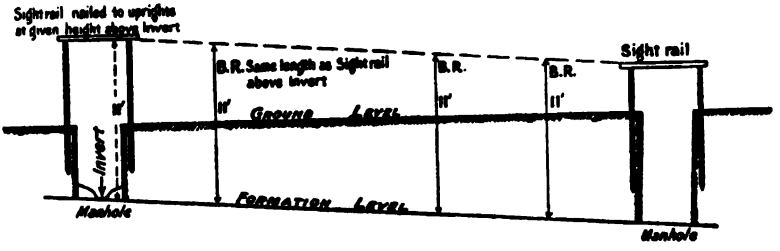


Fig. 118.

with a tape. Enter in the *Back Sight* column 14·00 and in the F.S. column 1·00. (See Fig. 119.) This gives a rise of 13 feet which added to the R.L. is the level of the top of the wall. Now enter the top of the wall as a B.S. of 0·00, and suppose the top of the wall is 15 feet above the ground (ascertained by the tape) on the other side there will be a fall of 15 feet, so that the next F.S. must be 15·00. Now proceed with the levelling, holding the staff at the foot of the wall, and entering the reading taken there as a B.S.

B. S.	Inter.	F. S.	Rise.	Fall.	R. L.	Remarks.
14·00	—	—	—	—	110·00	At foot of wall.
0·00		1·00	13·00		123·00	Top of wall.
—		15·00		15·00	108·00	Foot of wall other side.

Fig. 119.

If there are several walls to negotiate, such as are found at the backs of houses, between the gardens, the level might be set up on the wall, without its tripod.

When the staff is so near to the instrument that the feet figure does not come within the range of vision, direct the staff holder to move his finger up or down until it comes within sight. Now, by

looking away from the telescope directly on to the staff, the position of the finger will determine what is the 'feet' number to use. Sometimes the divisions cannot be read because the staff is too close to be focussed. When this is the case direct the staff holder to hold a pencil against the staff and move it up or down until its edge is cut by the line of collimation. The reading can then be determined as just described. This should only be adopted for intermediate sights, it is hardly accurate enough for change points.

Reciprocal Levelling.—This is a method of checking levels, from hill to hill, when proceeding through a valley, or when crossing a river, and it is not possible to set up the level in the halfway position. Set up the level at A (see Fig. 120) and take sights on to the staff at B and at C.

Note the difference of level. Next set up the instrument at D, the point D being the same distance from C as A is from B, and

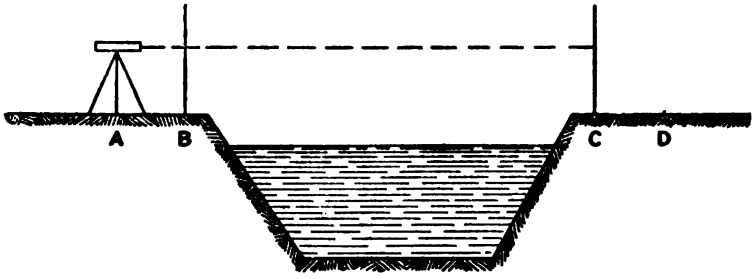


FIG. 120.

take sights on to the staff at C and B. Note the difference of level. The mean of the two results is the correct difference of level.

To locate a given level.—When it is required to put in a peg or mark a spot at a given R.L., the procedure is to deduct this R.L. from the height of the instrument, and the difference is the required reading on the staff. Then drive in a peg until, when the staff is held on it, the required reading is obtained on taking a sight.

Levelling with the Theodolite.—This may be done in two ways. The theodolite may be used in the same way as a Dumpy Level, in which case its adjustments must be properly seen to; or the vertical heights and distances may be worked out by trigonometry (as explained in the chapter on Trigonometry) from the angle of elevation or depression and the measurement along the slope. When a section is required in very hilly country this latter is practically the only method to be adopted. If ordinary levelling were adopted in such a case the number of readings required would be enormous. The theodolite is also invaluable for setting out

gradients. It is only necessar
required angle of elevation or
point in the line of gradient re
depression is worked out from th

Precise Levelling.—This is b
It may be defined as the carryi
coast to inland spots. Upon thi
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Bound set ends with.....
Bound set lacks vol.....

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FIG. 121.

Precise levels are also required when large engineering works have to be executed. Special methods and precautions have to be adopted in this form of levelling.

The Aneroid Barometer.—For determining altitudes rapidly within a certain degree of accuracy this instrument is very useful in a hilly country. It consists of a metal case with a glass front and is from 3 to 5 inches in diameter. Inside the case is a corrugated vacuum chamber with a strong spring above, a compound lever apparatus, dial, and hand. It depends for its action upon the pressure of the atmosphere on this vacuum chamber, the tendency of which is to collapse.

To use the barometer for measuring altitudes.—Turn the outer rim of the instrument until the index carried by it reads to the

same point as the index hand. On ascending the hill the hand travels backwards. Hold the aneroid horizontal and tap it gently during observation. Note the reading at the start and again at the end: the difference between the two gives the number of feet ascended. The observation should be made both ways, descending to the start. Always hold the instrument in the same position, when taking the readings, either horizontally or vertically.

When greater accuracy is required, correction for the temperature of the air, &c., must be made. There is a screw at the back of the aneroid by which it may be brought to the reading of a mercurial barometer at the position the mercury may be in. The instrument should be treated with care, and occasionally sent to be cleaned and adjusted. Fig. 121 shows a 3-inch aneroid barometer.

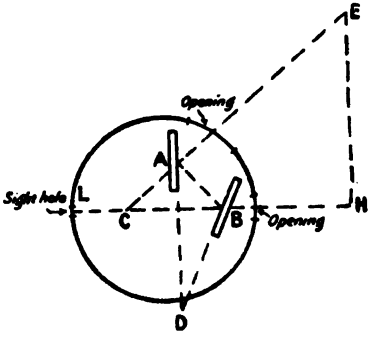


Fig. 122.

The **Apomecometer** is a small instrument 1¼ inches in diameter and ⅛ inch thick, like the optical square, except that the faces of the mirrors are fixed at an angle of 22° 30′ instead of 45°, and because the total deviation of a ray of light, after reflection successively at each mirror, is double their inclination, they consequently give a reflection of 45° instead of 90°. It was invented by R. C. Millar, A.R.I.B.A., and is very useful for finding the heights of buildings, trees, &c. From the inventor's description of the instrument the following notes are obtained:—

The instrument consists of two mirrors, A the index glass and B the horizon glass. (See Fig. 122.) These mirrors are fixed at an angle of 22° 30′ (∠ ADB). HE represents the vertical height required, and HC the horizontal line. AE represents the ray of light, or reflection of the image at E, striking the mirror at A, and from that reflected to the glass at B, half of which is silvered and formed into a mirror. Then, on looking through the aperture at L, the instrument being held edgewise in the hand, the point

H is seen by direct vision through the plain half, while the point E is seen reflected in the mirror. These two points must be made to coincide, which is done by moving the instrument backwards or forwards along the horizontal line CH. The openings in the instrument close as in the optical square, by rotation, so that the dust is kept out, when not in use.

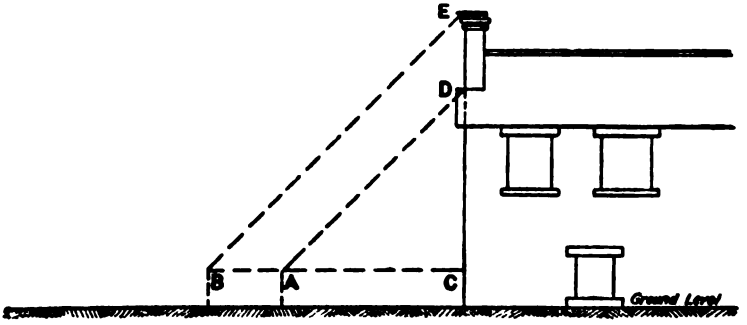


FIG. 123.

To use.—The angle measured being 45°, the horizontal distance is equal to the vertical. Holding the instrument in the hand at a distance away which is judged to be about the height of the object to be measured, observe by direct vision a point at the level of the eye on the wall of the house C. (See Fig. 123.) It is important to select a mark which is at the proper level of the eye and in a vertical line with the higher extremity

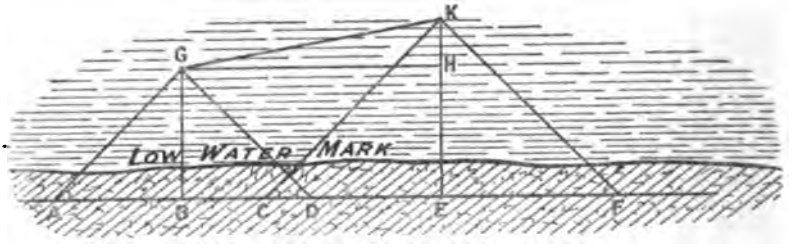


FIG. 124.

of the height to be measured. Now walk backwards or forwards until the point of the house D is seen reflected coincident with the spot C observed by direct vision. Then the distance AC of the observer from the house = the height of the house CD from the spot observed by direct vision on its wall. To this must be added the height of the observer's eye above the ground so as to fix the correct height of the house required. If a part of

an object be required to be measured such part may be taken on the horizontal plane as in Fig. 123, where AB = DE.

If the instrument is held on its side like the optical square, *horizontal* distances may be determined. The following figure (124) and notes taken from the inventor's explanation will make this clear.

'A base line is all that is necessary in order to take the observations. The angles at A, C, D, and F are taken with the instrument by moving backwards or forwards along the base line AF. Half AD equals AB or BG, the distance of the buoy at G; half CF = EF, or the distance of the other buoy from the base line. The distance HK equals EK *minus* BG: therefore in the right-angled triangle KHG, the sum of the squares of the sides containing the right angle is equal to the square of the hypotenuse, or the distance GK between the buoys.'

Fig. 125.

The **Clinometer** and its use has been already described. It is made in various forms and is very useful for taking the vertical angles of inclines and the slopes of cuttings and embankments.

The **Hypsometer** is an instrument for determining the boiling point of water. Water boils at a temperature according to the amount of atmospheric pressure surrounding it. From this fact it is possible to calculate the heights above sea level.

It consists of a cylindrical boiler (Fig. 125) with a telescopic funnel from which the steam escapes. Underneath the boiler is a spirit lamp. A thermometer is inserted through a tube in the funnel into the boiler. Various formulæ are employed for computing the difference in height between two spots. Its use, which is considered outside the scope of this book, may be ascertained from Stanley's 'Surveying Instruments.'

CONTOURS

Contours are levels of equal value. These levels are connected by lines which are called contour lines. All the points on a contour line are at the same height above an assumed base. Take as an example of illustration a tract of undulating land which has been flooded: the line which is left by the high-water mark of the flood represents a true contour, in that everywhere along it the level is the same. Fig. 126 shows contour lines round a hill, and also the manner in which a section may be prepared from them.

Contours are very useful to the surveyor in the development of a new country, the formation of roads, sewers, canals, railways, waterworks, &c. It is, however, a tedious and expensive business to define them. For the limited areas with which we have

to deal generally, 'spot levels,' which have been alluded to, will serve the purpose. The ordnance maps show contours, on the 1-inch map at 100-feet intervals, and on the 6-inch map at 100-feet intervals after the first two contours which are at 50 and 100 feet. The difference of level in feet between two contours is called the *Vertical Interval*, written V.I. The distance in yards on plan between any two contours is called the *Horizontal Equivalent*, written H.E. Fig. 127 shows what is meant. BC is the horizontal equivalent or distance between a contour at C and

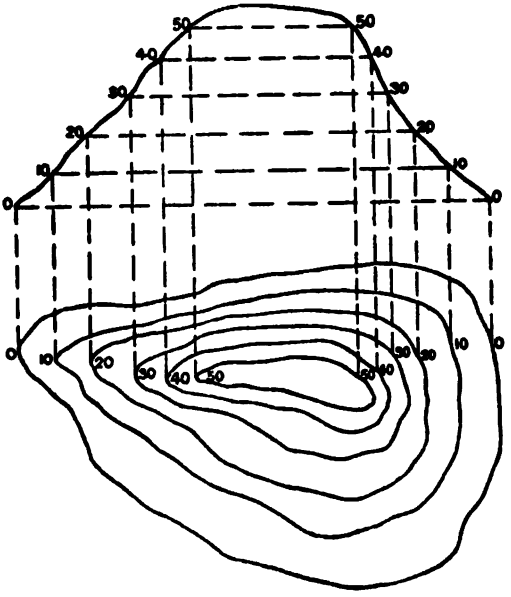


Fig. 126.

one at A. AB is the height of the contour at A above the contour at C and is called the vertical interval.

There are several ways of contouring. A very good method to adopt is to take sections through the length and width of the country to be contoured. On these sections the differences of height above base should be marked with pegs. The next step, and the tedious one, is to trace with the instrument and staff the line of level from peg to peg; the staff holder having to move about continually until he is in the correct position.

When the contours have been pegged out, they must then be surveyed, just as though they were so many fences, and drawn on the plan.

One of the best methods of putting them in is by traversing, which is explained in the chapter on Traversing.

To Read Contoured Plans.—This is an easy matter when the heights of the contours are figured in; it is only when these figures are absent that any difficulty arises.

The first thing to do is to identify on the map the lowest part of the country; this will usually be indicated by the largest stream or river shown. From this point the contours may be numbered from (say) 0 upwards.

The features which are of the greatest assistance in reading the heights are the *cols*. A col is a depression between two adjacent hills, or a pass in a mountain range.

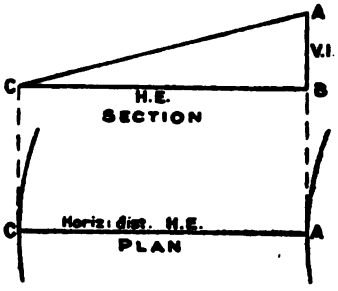


FIG. 127.

To compare the relative heights of two hills, count the intervals between the contours from the col to the top of each hill. The V.I. multiplied by the number of intervals gives the height of each hill. For instance, suppose the number of contour intervals from the col to one hill is 4, and to the other is 5; then, if the V.I, is 20 feet, the height of one hill is 80 feet and the other 100 feet.

A section drawn from one point to another (Fig. 126) will show whether two points on the plan are visible from each other; but a close study of the contours will avoid the necessity of this in general because it is obvious that if the contours are closer together at the top of the hill the hill is *concave*, and *convex* if they are closer together at the bottom.

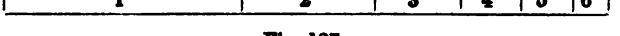


Fig. 127A.

A scale of **slopes** or **horizontal equivalents** is sometimes drawn on plans. This scale is obtained by working out the horizontal equivalents (Fig. 127) for varying degrees of slope and a given V.I., and then drawing the lengths found to the scale of the map. Fig. 127A is a scale of H.E. for 20 feet V.I. on a six inches to a mile plan.

If the distance is measured between the contours on the plan by this scale, the slope of the ground at any place is at once ascertained. For instance, if the distance from one contour to another on the plan is the same as the distance indicated on the scale of slopes by (say) 4°, then the slope between them is 4°.

The solution of right-angled triangles, whereby these H.E.'s may be worked out, is explained in Chapter VIII., but the calculation may be simplified by the use of an easy formula which is derived from the fact that in a right-angled triangle having a slope of 1° there will be a rise of 1 *foot in* 57·3 *feet.*

A 2° slope, therefore, will have a rise of 1 foot in $\frac{57{\cdot}3}{2}$, or (say) 1 in 29, and a rise of 20 feet in $\frac{57{\cdot}3 \times 20}{2}$; a 3° slope will have a rise of 1 foot in $\frac{57{\cdot}3}{3}$, and 20 feet in $\frac{57{\cdot}3 \times 20}{3}$, and so forth.

From this the following formula is obtained :—

$$\text{H.E.} = \frac{57{\cdot}3 \times \text{V.I.}}{\text{D}}$$

where D = the degree of slope.

This formula is approximate; for any degree of slope over 20°, or for greater accuracy, the solution must be made by trigonometry.

By the same formula D and V.I. can, of course, be found.

The angle of slope can be obtained from contour lines on a plan by measuring with the scale the horizontal distance between two adjacent contours : this gives H.E., and V.I. is the vertical contour interval of the plan.

Then from the above formula :—

$$\text{D} = \frac{57{\cdot}3 \times \text{V.I.}}{\text{H.E}}$$

Also

$$\text{V.I.} = \frac{\text{D} \times \text{H.E.}}{57{\cdot}3}$$

The necessity of having to construct a scale of H.E. for different scales of plan is obviated by the adoption of what is known as *the normal system of contours.* By this system—the basis of which is that on a scale of six inches to a mile the V.I.'s between the contours shall be 20 feet—the distance between the contours on every plan is always the same for the same slopes, no matter what the scale may be.

Thus, when a scale of H.E. is not shown on a plan, we may assume that the contours are on the normal system ; and, in this case, the V.I. for any plan can always be ascertained by dividing 120 by the scale of the plan in ir ches to the mile, or by dividing the denominator of the R.F. by 528.

Adjustments

The Adjustments of the Dumpy Level. — These are divided into two kinds :—

1. Temporary.
2. Permanent.

The **temporary adjustments** are those which the surveyor makes every time he uses the instrument, and consist of :—

(1) Accurate '*setting up*' and '*levelling*' which have been already described.

(2) The elimination of '*Parallax*.'

Parallax is due to improper focal adjustment whereby the foci of the object glass and eyepiece fail to coincide with the cross hairs of the diaphragm. When parallax exists, an indefiniteness of reading is produced, and by moving one's head up or down in a vertical line the cross webs appear to move also. It is necessary, of course, that the cross webs should remain fixed upon the staff, no matter whether one moves one's head or not.

To correct the error, slightly move the eyepiece pushing it in or pulling it out until you see the cross webs clearest and most distinct—that is, until the correct magnifying power of the eyepiece has been found. When this is once done there should be no occasion to alter the eyepiece for the rest of the day's work, all future corrections being made by the milled-head screw at the side of the telescope which gives correct focus. In practice, however, slight adjustment of the eyepiece may be found necessary for varying distance readings. If the object moves, the O.G. requires adjustment. If the cross webs move the eyepiece requires adjustment.

Permanent Adjustments.—(1) **Adjustment of the bubble tube, at** right angles to the vertical axis of motion—i.e. to make the instrument ' traverse,' so that the bubble remains in the centre of its run in every position of the telescope.

Test.—Level the instrument so that the bubble remains in the centre of its run in two positions of the telescope at right angles to one another.

Now turn it through a further 90° or 180° from its original position and place it over the same two foot screws again. If the bubble now remains in the centre of its run, all is well, but if not—

Adjustment.—Note carefully the amount which the tube requires to be raised or depressed, and correct *half* by the foot screws and the other *half* by the opposing nuts (marked B, B in Fig. 92) at the one end of the bubble tube, by means of the tommy pin. Repeat the process, if necessary, until the bubble retains the centre during a complete revolution of the telescope.

(2) **Adjustment of the line of collimation,** parallel to the adjusted bubble tube—i.e. to ensure that the line of collimation, or line of

observation through the telescope, is horizontal when the bubble is in the centre of its run. This is the most important adjustment of the level.

Test.—Choose a fairly level piece of ground (see Fig. 128) and mark two spots with pegs having squarely cut tops and driven to within a few inches of the ground, about 1 chain apart. Set up the instrument exactly midway between the two pegs and take readings to the staff held on each peg. Suppose the readings are 3·50 and 3·75 respectively. Lower the 3·50 peg 0·25 in order to make the readings exactly the same. The two pegs will then be on the same level. Now remove the instrument and set it up as close as is practicable behind either peg. Read the staff held on the nearest peg. Suppose it reads 3·60. Also read the staff held on the further peg and if the instrument is in adjustment the reading on this peg will be 3·60 too. Suppose however it reads 3·75, then—

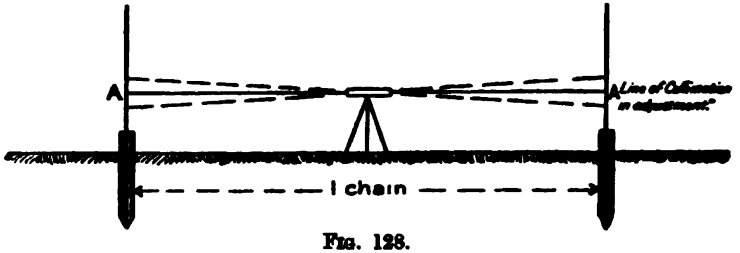


FIG. 128.

Adjustment.—Lower the diaphragm by means of the adjusting screws (F, F in Fig. 92) until the readings on both staffs coincide.

Care should be exercised in this adjustment to see that both the adjusting screws of the diaphragm, after completion of the adjustment, are firm.

The Adjustments of the Y Level.—Temporary as before.

Permanent.—(1) Adjustment of the collimation of the telescope.

Test.—Select some test object not less than half a chain away from the instrument. Set up the instrument in such a way that when the telescope is directed to this object it lies exactly over one of the foot screws, or a pair of the foot screws, as the case may be. All parallax being eliminated the test mark must be accurately bisected by the cross-web. Now open the Y's and carefully rotate the telescope halfway round in the Y's until the cross-web is again horizontal. If the test mark is not now bisected but comes above or below the cross-web then—

Adjustment.—Correct half the error by the foot screw underneath the telescope and half by the screws at the eye end of the telescope. Repeat, if necessary, until accuracy results.

(2) **Adjustment of the axis of the telescope, so that it may be** exactly at right angles to the vertical axis.

Test.—Focus the telescope upon the test mark and accurately bisect it by the horizontal cross-web. Next lift the telescope out of its Y's, and reverse it end for end in them. Re-direct the telescope to the test mark which should still be bisected by the cross-web, but if it is not then—

Adjustment.—Correct half the error by the foot screw beneath the telescope and half by the circular lock nuts (B, B, Fig. 96). Repeat, if necessary, until accuracy results.

(3) **The adjustment of the bubble tube.**—Set up the instrument as nearly level as possible by the foot screws. Place the telescope parallel to two of the foot screws, and bring the bubble to the centre of its run by turning one of them. Next turn the telescope halfway round on its vertical axis, and bring the bubble to its centre, half by the foot screws and half by the circular nut at the end of the bubble tube. Now turn the telescope only a quarter round, so that it lies over the other foot screw, or other pair of foot screws, as the case may be, and bring the bubble to the centre of its run by the aid of the foot screw or screws. Again turn the telescope halfway round, and if there be any error correct it half by the foot screws and half by the circular nuts at the end of the bubble tube. The instrument should now traverse properly, but if it does not, repeat until accuracy results.

CHAPTER VII

LOGARITHMS

The reader is recommended to obtain a copy of Chambers's 'Mathematical Tables'; these notes are given in conjunction with this work.

By means of logarithms, which are auxiliary numbers, the labour of calculation is considerably lessened.

Multiplication	can	be	performed	by	*Addition.*
Division	,,	,,	,,	,,	*Subtraction.*
Involution	,,	,,	,,	,,	*Multiplication.*
Evolution	,,	,,	,,	,,	*Division.*

Every number is some definite power of 10 and so we can define the *common logarithm of a given number as that power to which* 10 *must be raised in order to produce the given number.*

Example.—The logarithm	of	100,000	=	$5 = 10^5$
,,	,,	10,000	=	$4 = 10^4$
,,	,,	1,000	=	$3 = 10^3$
,,	,,	100	=	$2 = 10^2$
,,	,,	10	=	$1 = 10^1$
,,	,,	1	=	$0 = 10^0$
,,	,,	0·1	=	$-1 = 10^{-1}$
,,	,,	0·01	=	$-2 = 10^{-2}$
,,	,,	0·001	=	$-3 = 10^{-3}$
,,	,,	0·0001	=	$-4 = 10^{-4}$
,,	,,	0·00001	=	$-5 = 10^{-5}$

The log of 10 is 1, and the log of 100 is 2, therefore the logs of all the numbers between 10 and 100 are greater than 1 and less than 2. It will be seen from the above that it is very simple to find the log of any number that is a definite power of 10.

Example.—If the number contains two figures then the log is 1 (log of 10 = 1), if three figures, then log is 2 (log of 100 = 2), and so forth. That is to say, the log is always one less than the number of integral figures. But this is only for definite powers of 10, what about all those numbers which are not? Look in the tables on page 1, and we find :—

Log 1 = 0
„ 2 = 0·3010300
„ 3 = 0·4771213
„ 4 = 0·6020600
„ 5 = 0·6989700
„ 6 = 0·7781513
„ 7 = 0·8450980
„ 8 = 0·9030900
„ 9 = 0·9542425
„ 10 = 1·0000000
„ 11 = 1·0413927
„ 12 = 1·0791812

From this it will be seen that there are two parts to a logarithm—the figures before the decimal point and those after it. The figures to the left of the decimal point are called the *Characteristic* of the log and those to the right the *Mantissa*.

As explained, the characteristic is ascertained at once by inspection, being always one less than the number of integral figures in the number, and the mantissa is found from the tables. A few examples will make this clear.

(*a*) What is the log of 42? Look in the tables on page 1 and in the extreme left-hand column which is headed 'No.' will be found the figures 42. Against this are the figures 6232493. These are the figures to the right of the decimal point and are called the mantissa of the log. As the number contains two figures, therefore the characteristic is 1, and the log of 42 therefore equals—

1·6232493

(*b*) What is the log of 6·2? If there is a decimal point in a number *only the characteristic is affected*, and not the mantissa. Against the number 62 are seen the figures 7923917, but what is the characteristic? There is only one *integral figure*, therefore, as the characteristic is always one less, it is in this case 0, and the log of 6·2 is—

0·7923917

(*c*) What is the log of 0·83? Look out the number 83 and the mantissa is found to be 9190781. What is the characteristic? In this case it is negative and is -1. In order that the log may not appear to be entirely a negative quantity it is written $\bar{1}$, with the minus sign above instead of in front. The log of 0·83 therefore is—

$\bar{1}$·9190781

(*d*) What is the log of 0·083? Look out 83 as before and the mantissa is 9190781. What is the characteristic? It is -2 and the log of 0·083 is therefore—

$\bar{2}$·9190781

(*e*) What is the log of 0·0083? The mantissa is the same 9190781, and the characteristic this time is — 3, therefore the log of 0·0083 is—

$$\bar{3}\cdot9190781$$

(*f*) What is the log of 0·000064? Look out number 64 and the mantissa is found to be 8061800. The characteristic will be — 5, and the log of 0·000064 is—

$$\bar{5}\cdot8061800$$

It will be seen from the last four examples that the characteristic is easily ascertained by noting the position of the *first significant figure after the decimal point* and prefixing the minus sign. Thus in example *c* the first significant figure, 8, is in the *first* position, therefore the characteristic is — 1.

In example *d* the first significant figure, 8, is in the *second* position, therefore the characteristic is — 2.

In example *e* the first significant figure, 8, is in the *third* position, therefore the characteristic is — 3.

And in example *f* the first significant figure, 6, is in the *fifth* position, therefore the characteristic is — 5.

When, however, we arrive at page 6 we shall notice that the method of showing the logs is rather different. Underneath the letters No. we see four figures, and at the top of the page the figures 0, 1, 2, 3, 4, 5, 6, 7, 8, 9. These represent the *fifth figure in the number column*. We are, consequently, able to find the logs of numbers containing five figures.

As before a few examples should make this clear.

(*a*) What is the log of 1001? Against the figures 1001 in the No. column we see 4341. These figures are to be preceded by 000 and therefore the mantissa is 0004341. In order to save space the first three figures are only written once, and 000 precedes all the figures until 001 is found to precede the next following four figures. The characteristic will be 3, as there are four whole numbers, and the log of 1001 is therefore—

$$3\cdot0004341$$

(*b*) What is the log of 10001? Look in the No. column for the first four figures and under the log column headed 1 for the fifth figure of the number. The figures found are 0000434. As the number has five figures, the characteristic will therefore be 4 and the log of the number 10001 equals—

$$4\cdot0000434$$

(*c*) What is the log of 37374? Look in the No. column for 3737 and under the log column headed 4 the figures found are 5696. Prefix the first three figures 572 and the mantissa is 5725696.

What is the characteristic? The number has five figures therefore the characteristic is 4 and the log of 37374 equals—

4·5725696

A slight further alteration in the method of finding the logs of numbers containing more than five figures must now be noticed. Most tables do not give the logs of numbers higher than 108000.

(*d*) What is the log of 46176532? Look out the mantissa of the log of the first five figures 46176. The mantissa of the log of 46176 = 6644163. Now refer to the extreme right-hand column headed 'Diff.' Choose the nearest small column, in this case the only one, headed 94. By means of the figures in this column we are enabled to ascertain what amount must be added to the log of 46176 in respect of the remaining figures 532, in the following way :—

Mantissa of log 46176 =	6644163
The difference for 5 =	47
,, ,, ,, 3 =	28
,, ,, ,, 2 =	19
∴ The log of 46176532 =	7·664421299

The positions of the difference figures should be carefully noticed.

(*e*) What is the log. of 6644232?

Mantissa of log 66442 =	8224427
Difference for 3 =	20
,, ,, 2 =	13
∴ Log of 6644232 =	6·82244483

(*f*) What is the log of 105557?

10555 =	0234582
7 =	288
∴ Log of 105557 =	5·0234870

If the log of 105557 is looked out on page 197 it will be found to one more place of decimals, viz. 5·02348704.

Pages xi and xii, sec. 6 *d*, show a slightly different method of finding the logs of numbers containing more than five figures without recourse to the 'Diff.' column.

Some of the figures in the tables have a line drawn over them. This means that the four figures over which the line is drawn are to be preceded by the *three figures given just after instead of before them.*

Example :—The log of 82604 = 4·9170011 and not 4·9160011. Also the number corresponding to the log 4·9180041 = 82795 and not 82805.

We have considered the looking out of the log of a number, we must now consider the looking out of the number which corresponds to the log. The process will, of course, be exactly the reverse.

To find the number which corresponds to a given log.—Look

in the tables for the nearest log just *below the given one.* The difference between this and the given log must be used for finding out what figures must be added to the five figures of the number already found. Consult the small difference column at the side and take the nearest difference figure given in it, which is just below the difference of the logs already found. Against this will be found the sixth figure of the number.

Subtract, add 0 to the remainder, and again look in the 'Diff.' column for the next below and so obtain the seventh figure of the number. Repeat until sufficient figures are obtained. A few examples should make the above explanation quite clear.

(*a*) What is the number whose log is 4·3678921? Look in the tables for the log next below and subtract it from 4·3678921. Then look in the 'diff.' column for the nearest 'diff.' number just below.

Example. The given log = 4·3678921
The next below = 4·3678775 = the log of 23328
The difference = 146

In the 'diff.' column (187) we find that the next below 146 is 131, which stands for 7. Thus 7 is the sixth figure of the number . . . . 131 stands for 7

Subtract 131 from 146 and add 0 . 150

The nearest 'diff.' below 150 is 131, but it will go out at 150 and we have sufficient figures . . . . . 150 stands for 8

∴ The number = 23328·78

NOTE.—As this process is the reverse of finding the log, *the numbers must contain one more figure to the left of the decimal point than is indicated by the characteristic of the given log.*

In the example just given the characteristic of the given log is 4, therefore the number must contain 5 figures to the left of the decimal point as shown.

(*b*) What is the number whose log is 6·1234321?

Given log =	6·1234321	
Next below =	6·1234269	= log of 13287
Difference =	52	
Next difference below =	33	= 1
Subtract and add 0 =	190	
Next difference below =	163	= 5
Subtract and add 0 =	270	
Next difference below =	261	= 8

∴ The number = 1328715·8.

Further decimal places could be found if required. As the characteristic of the given log is 6, therefore the number must contain 7 figures to the left of the decimal point as shown.

If the given log contain more than seven places of decimals those beyond the seventh must be brought down instead of adding 0's.

(*c*) What is the number whose log is 3·987654222 ?

Given log = 3·987654222
Next below = 3·9876529 = log of 97197
13
9 = 2
42
41 = 9
12
14 = 3

It is as well to finish off, as we have done, with the nearest difference whether above or below.

∴ The number = 9719·7293.

The Use of Logarithms

To multiply two numbers together.—Find the log of each number. Add them together and the total will be the log of the answer.

Example.—Multiply 231·4 by 5·062.

Log 231·4 = 2·3643634
Log 5·062 = 0·7043221
Log of answer = 3·0686855
Next lower = 3·0686681 = 11713
174
149 = 4
250
261 = 7
Answer = 1171·347

To divide one number by another.—Find the log of each number, subtract the log of the divisor from the log of the dividend, and the result will be the log of the answer.

Example.—Divide 0·06321 by 124·56.

Log. of 0·06321 = $\bar{2}$·8007858
Log of 124·56 = 2·0953786
Log of answer = $\bar{4}$·7054072
Next lower = $\bar{4}$·7054018 = 50746
54
52 = 6
20
17 = 2

Answer = 0·0005074662.

It will be noticed in the above example that calculations with negative characteristics are made according to the rules of algebraic subtraction. The sign of the bottom number is changed and added to the top. Thus to subtract 2 from $\bar{2}$ the result is found by adding $\bar{2}$ to $\bar{2}$ which gives $\bar{4}$.

To perform involution (i.e. to raise a number to a required power).—Find the log of the number; multiply it by the exponent of the power and the result will be the log of the answer.

Example.—(*a*) Find the square of 731·77.

Log of 731·77 = 2·8643746
2
Log of answer = 5·7287492
Next lower = 5·7287433 = 53548
59
57 = 7
20
16 = 2
40
41 = 5

Answer = 535487·25

(*b*) Find the fourth power of 9·163.

Log of 9·163 = 0·9620377
4
Log of answer = 3·8481508
Next lower = 3·8481460 = 70493
48
43 = 7
50
50 = 8

Answer = 7049·378

To perform evolution (i.e. extract the root).—Divide the logarithm of the given number by the exponent of the root, and the result will be the log of the answer.

Example. (*a*) Find the cube root of 54321.

Log of 54321 = 4·7349678
4·7349678 ÷ 3 = 1·5783226 = log of answer.
Next below = 1·5783182 = 37872.
44
46 = 4

Answer = 37·8724

(*b*) **Find the cube root of 0·054321**

$$\text{Log of } 0{\cdot}054321 = \bar{2}{\cdot}7349678$$

Here the negative characteristic is not divisible by the divisor 3, so that we must add such a negative number to it as will make it divisible, and prefix an equal positive integer to the fractional part of the log.

$$\text{Thus } 3)\overline{3} + 1{\cdot}7349678$$

$$\overline{1}{\cdot}5783226$$

(The value of the log is unaltered because $\overline{1}$ and 1 or 0 are added to it.)

$$\text{Next below } \overline{1}{\cdot}5783182 = 37872$$

$$44$$

$$46 = 4$$

$$\text{Answer} = 0{\cdot}378724$$

See pages xiii, xiv, xv, and xvi in the Tables.

CHAPTER VIII

TRIGONOMETRY

TRIGONOMETRY treats of the measurement *by calculation* of the different parts of a triangle. It is a branch of mathematics which is essential to Surveying.

Every triangle has six distinct parts, three angles and three sides. If we know any three parts (except the three angles) we can ascertain by calculation the remaining three parts. We could, of course, ascertain the three remaining parts by 'plotting' and scaling also, but this method is not sufficiently accurate, and so we resort to trigonometry, which enables us *to calculate without plotting* any of the parts which we could have ascertained by plotting and scaling.

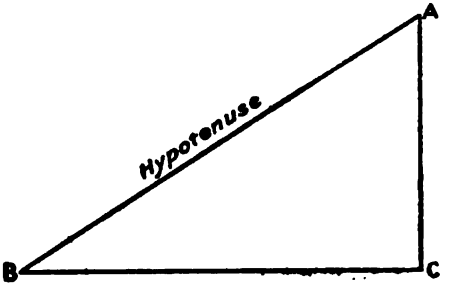


FIG. 129.

The difficulty is to obtain a common basis of measurement because angles are expressed in *degrees*, *minutes*, and *seconds* (a right angle being 90°) and sides according to the ordinary standard of linear measurement such as chains, yards, feet, &c. It will be perfectly obvious that in a sum involving the multiplying together, &c., of such terms as degrees and minutes by chains, or yards, we should not advance much towards a solution.

It is necessary to obtain some means whereby we can express angles and sides in the same terms. Indirectly angles may be expressed in terms of linear dimensions by means of ratios. In the case of any angle, if we drop a perpendicular from one of the two lines containing it to the other line, any two sides of the triangle thus formed will always bear to one another a fixed proportion or ratio. *By means of these ratios we can represent an angle in a calculation which contains linear dimensions.*

There are *six ratios* which can be formed out of the sides of a right-angled triangle. They are called *Functions* and are as follows :

$$\frac{\text{Perpendicular}}{\text{Hypotenuse}} \quad \frac{AC}{AB} = \text{Sine of the angle B.}$$

$$\frac{\text{Base}}{\text{Hypotenuse}} \quad \frac{BC}{AB} = \text{Cosine} \quad ,,$$

$$\frac{\text{Perpendicular}}{\text{Base}} \quad \frac{AC}{BC} = \text{Tangent} \quad ,,$$

$$\frac{\text{Base}}{\text{Perpendicular}} \quad \frac{BC}{AC} = \text{Cotangent} \quad ,,$$

$$\frac{\text{Hypotenuse}}{\text{Base}} \quad \frac{AB}{BC} = \text{Secant} \quad ,,$$

$$\frac{\text{Hypotenuse}}{\text{Perpendicular}} \quad \frac{AB}{AC} = \text{Cosecant} \quad ,,$$

It should be very carefully noted that in right-angled triangles the side opposite the right angle is called the *Hypotenuse* and the remaining sides the base and perpendicular. Now in trigonometry the *side opposite the angle which is being used in the solution of the triangle is called the Perpendicular.*

Thus in Fig. 129 the side AC is the perpendicular with respect to the angle B, but with respect to the angle A, BC is the perpendicular and—

$$\text{Sine A (}\textit{written}\text{ sin)} = \frac{BC}{AB}$$

$$\text{Cosine A (}\textit{written}\text{ cos)} = \frac{AC}{AB}$$

$$\text{Tangent A (}\textit{written}\text{ tan)} = \frac{BC}{AC}$$

$$\text{Cotangent A (}\textit{written}\text{ cot)} = \frac{AC}{BC}$$

$$\text{Secant A (}\textit{written}\text{ sec)} = \frac{AB}{AC}$$

$$\text{Cosecant A (}\textit{written}\text{ cosec)} = \frac{AB}{BC}$$

It is important to bear this in mind as the beginner very often loses sight of it. The functions must, of course, be learnt by heart, but the following mnemonic will be of great assistance:—*P*eter *H*as // *B*een *H*ere // *P*laying *B*illiards //.

Taken in pairs and using the first letter of each word we get Peter Has, Perpendicular over Hypotenuse = sine: Been Here, Base over Hypotenuse = cosine: Playing Billiards, Perpendicular over Base = tangent. It will be seen that the cotangent, secant, and cosecant are the reciprocals of the tangent, cosine, and sine respectively.

Before proceeding further let us first take note of the following facts:—

(*a*) All three angles of a triangle together equal 180°.
(*b*) In a right-angled triangle the square on the hypotenuse is equal to the sum of the squares on the other two sides.
(*c*) The complement of an angle is that which must be added to it in order to make a right angle.
(*d*) The supplement of an angle is that which must be added to it in order to make two right angles.

Example.

The complement of 45°	= 45°	and the supplement	= 135°
,, 26° 13′	= 63° 47′	,,	= 153° 47′
,, 80° 10′	= 9° 50′	,,	= 99° 50′

Referring again to Fig. 129—

$$\frac{AC}{AB} = \sin B$$

also

$$\frac{AC}{AB} = \cos A$$

$$\therefore \quad \sin B = \cos A$$

The sine of an angle = the cosine of its complement.
,, tangent ,, = ,, cotangent ,,
,, secant ,, = ,, cosecant ,,

In a right-angled triangle, therefore, if one of the acute angles be known, the other, its complement, must be the difference between it and 90°; and if any two angles of a triangle be known, the third must be 180 *minus* their sum.

The value of any function can be found if the number of degrees be known or the number of degrees can be ascertained if the function be known. For example, an angle may be described as such that its tangent is $\frac{1}{2}$. Now tangent means perpendicular divided by base, consequently the angle is such that the base is twice the length of the perpendicular. By plotting a triangle with a base twice as long as the perpendicular the angle is obtained whose tangent is $\frac{1}{2}$. With a protractor the angle would be found to contain about 26° 34′. But by means of Chambers' 'Mathematical Tables' we are able to find out the numerical values of the functions of angles.

How to use the Tables of Functions of Angles.—Sines and Cosines.—On page 263 will be found columns headed 'Natural

Sines, Cosines, Chords, &c.' At the top of the page is 0° and at the bottom 89°. On the extreme left is a column of minutes reading from 0 to 60 downwards, and on the extreme right is a similar column reading upwards. It will be also noticed that the column headed 'Sine' is called 'Cosine' at the bottom and *vice versa*: and the number of degrees at the top is just one less than the complement of the number of degrees at the bottom of the page.

What is the sine of 2° 16′?—Look on the page headed 2° and follow down the column of minutes until you come to 16—the figures in the sine column against this number are 0395505. All the figures given are decimals, so a decimal point must be understood where it is not shown.

$$\therefore \sin 2° 16′ = 0{\cdot}0395505$$

What is the cosine?—Look down the column headed 'cosine,' using the same minute column, and the figures found are 9992176.

$$\therefore \cos 2° 16′ = 0{\cdot}9992176$$

Note very carefully that when the number of degrees appears at the top of the page the left-hand minute column must be used, and when the number of degrees appears at the bottom of the page the right-hand minute column must be used, always. This is very important.

What is the sine of 87° 44′?—This time the number of degrees appears at the bottom of the page (as do all the numbers from 45° to 90°) so that we must use the right-hand minute column.

$$\therefore \sin 87° 44′ = 0{\cdot}9992176$$

What is the cosine? Look up the column marked cosine and using the same minute column—that is, the right-hand one—we find that—

$$\cos 87° 44′ = 0{\cdot}0395505$$

It will be seen from this that the sine of an angle = the cosine of its complement, for 87° 44′ is the complement of 2° 16′. By printing the work so as to read from the top and the bottom, the publisher thereby saves space.

Tangents, Cotangents, Secants, and Cosecants.—These are more simple to read. The tables follow immediately after those just considered—namely, sines and cosines.

Example.

$$\begin{aligned} \tan 40° 3′ &= 0{\cdot}8405878 \\ \cot 49° 9′ &= 0{\cdot}8647009 \\ \sec 73° 4′ &= 3{\cdot}5594042 \\ \operatorname{cosec} 13° 4′ &= 4{\cdot}2273373 \end{aligned}$$

In ordinary work it is not usually necessary to read an angle more precisely than to the nearest minute, but if it is required to read to seconds, the method of finding out the logarithmic functions is shown on page xxii in the Tables.

Solution of Right-Angled Triangles

RULE I.— *If the length of a side be required, place this side over one of which the length is known, and state what function it makes.*

Example.—Solve the triangle ABC (Fig. 130), when the angle C = 90°, A = 32° 32′, and AC = 40 feet.

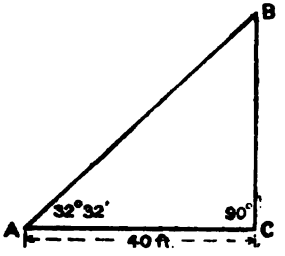


FIG. 130.

Find the length of BC first. Therefore, place BC over AC whose length is known and state the function it makes. BC is the perpendicular (A being the angle in question, or that which we are using in the solution) and AC is the base.

Perpendicular ÷ Base = tangent

$$\therefore \frac{BC}{AC} = \tan 32° 32'$$

$$\therefore BC = \tan 32° 32' \times AC$$
$$= \tan 32° 32' \times 40$$

Now look in the tables for the numerical value of tan 32° 32′. It is 0·6378885.

$$\therefore BC = 0{\cdot}6378885 \times 40$$
$$\therefore BC = 25{\cdot}51554$$

Now find AB.

$$\frac{AB}{AC} = \sec 32° 32'$$

$$\therefore AB = 40 \times \sec 32° 32'$$
$$\therefore AB = 40 \times 1{\cdot}1861289$$
$$\therefore AB = 47{\cdot}445156$$

The angle B must, of course, be 90° − 32° 32′ = 57° 28′.

The three unknown parts have thus been found and the triangle solved.

RULE II.— *If an acute angle be required and the other be not known, form a vulgar fraction with the two given sides and state, as an equation, what function it represents.*

Solve the triangle ABC (Fig. 131) when C = 90° and BC = 40 and AC = 30.

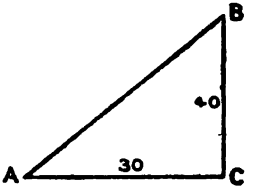


FIG. 131.

$$\frac{BC}{AC} = \tan A$$

$$\therefore \frac{40}{30} = \tan A$$

$$\therefore 1{\cdot}3333333 = \tan A$$

Look in the tables of natural tangents for these figures, and note what angle it represents. The figures are given in numerical order and the nearest to 1·3333333 is 1·3334900 which is against the angle 53° 8′.

$$\therefore \text{the angle } A = 53° 8'$$

Now find the side AB.

$$\frac{AB}{AC} = \sec 53° 8'$$

$$\therefore AB = 30 \times \sec 53° 8'$$
$$\therefore AB = 30 \times 1{\cdot}6667920$$
$$\therefore AB = 50$$

Of course the side AB can be found by the rule of Euclid (I. 47), which states that the square on the hypotenuse = the sum of the squares on the other two sides.

$$AB^2 = BC^2 + AC^2$$
$$\therefore AB^2 = 1600 + 900$$
$$\therefore AB^2 = 2500$$
$$\therefore AB = \sqrt{2500}$$
$$\therefore AB = 50$$

The application of the above two rules, for the solution of right-angled triangles has many practical uses such as where the difference

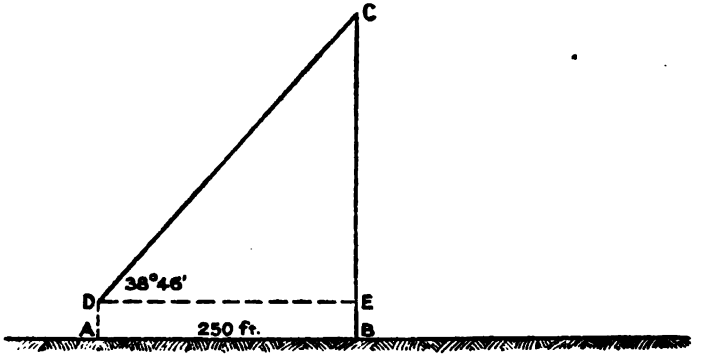


Fig. 132.

of level between two spots is required when using the theodolite; for finding the height of buildings, trees, hills, &c.; for ascertaining the difference of latitude or longitude between two spots; and many other cases.

It is an excellent plan always to draw a figure as near as may be to the work in hand, before beginning its solution.

The following examples will serve to show the method of solving simple problems.

1. At a distance of 250 feet from a building the angle of elevation is found to be 38° 46′. The ground is level between the building and the observer, and the height of the eye may be taken as 5 feet. Find the height of the building. (Fig. 132.)

Let BC represent the building whose height is required. AB is 250 feet measured on the ground which is level from the base of

the building, DE is therefore a level line 5 feet above the ground level. EDC is the angle of elevation = 38° 46′.

Find CE.

$$\frac{CE}{DE} = \tan 38° 46'$$

$$\therefore CE = 250 \times 0{\cdot}8030632$$

$$\therefore CE = 200{\cdot}7658 \text{ feet}$$

To this add the height of the observer's eye.

$$\therefore \textit{The height of the building} = 205{\cdot}7658 \textit{ feet}$$

(*a*) If the ground is not level as in Fig. 133 it is necessary to find

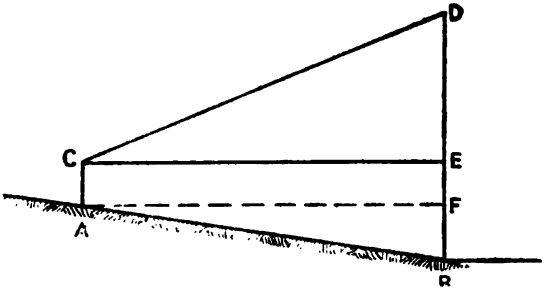


Fig. 133.

the difference in level between A and B. Then if the slope AB be measured the horizontal distance AF can be calculated ($AF^2 = AB^2 - FB^2$). From the horizontal distance AF the triangle may be solved and DE found. EB must be added to DE for the required height.

(*b*) Fig. 134 represents a section over hilly ground, the dimensions and angles being as shown. The point A is 800 feet above sea level calculate the level of the point E, and the horizontal distance from A to E.

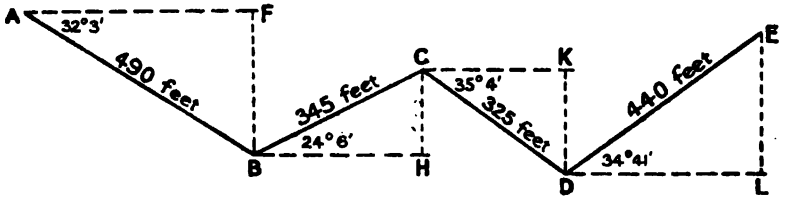


Fig. 134.

In solving problems of this sort it is important to tabulate the work, as by doing so it will not only make the actual working easier and quicker, but also give a more clear and concise result.

Fig. 135 shows the tabulated solution.

Station	Equation	Working	Rise	Fall	Distance	H. A. B.	Total Distance
A						800·00	0
	$\frac{BF}{AB}$ = sin 32° 3′	0·5306591 490 212 2636400 47 7593190 260·0229590		260·02			
	$\frac{AF}{AB}$ = cos 32° 3′	0·8475853 490 339 0341200 76 2826770 415·3167970			415·31		
B						539·98	415·31
	$\frac{CH}{BC}$ = sin 24° 6′	0·4083305 345 122 4991500 16 3332200 2 0416525 140·8740225	140·87				
	$\frac{BH}{BC}$ = cos 24° 6′	0·9128342 345 273 8502600 36 5133680 4 5641710 314·9277990			314·92		
C						680·85	730·23
	$\frac{KD}{CD}$ = sin 35° 4′	0·5745292 325 172 3587600 11 4905840 2 8726460 186·7219900		186·72			
	$\frac{CK}{CD}$ = cos 35° 4′	0·8184841 325 245 5452300 16 3696820 4 0924205 266·0073325			266·01		
D						494·13	996·24
	$\frac{EL}{ED}$ = sin 34 °41′	0·5690403 440 227 6161200 22 7616120 250·3777320	250·38				
	$\frac{DL}{ED}$ = cos 34° 41′	0·8321155 440 332 8462000 33 2846200 366·1308200			366·13		
E						744·51	1362·37

FIG. 135.

The point is, therefore, 744·51 feet above sea level and 55·49 feet lower than A. The horizontal distance from A to E is 1362·37 feet.

Logarithmic Functions of Angles.—By using logs and logarithmic functions of angles the work is shortened. So far we have learnt to solve right-angled triangles without logs and have consequently used *natural* functions; but if we use logs we must also use logarithmic functions. The logarithmic functions will be found on page 203 and following pages. These tables are read in precisely the same way and *it is only necessary to deduct* 10 *from the figures actually found and the remainder is the actual log required.*

Example.

$$\text{The log sin of } 8° 14' = 9·1559574 - 10$$
$$= \bar{1}·1559574$$
$$\log \tan 57° 20' = 0·1930286$$

Ten has been added to all the figures in these tables, as can be easily seen if you look out the natural sine of any number of degrees and then find the log of the figures so obtained.

The use of logs in solving right-angled triangles.—Solve the right-angled triangle ABC (Fig. 136), the dimensions being as shown.

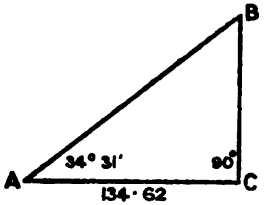


Fig. 136.

$$\frac{BC}{AC} = \tan 34° 31'$$

$$\therefore BC = 134·62 \times \tan 34° 31'$$

$$\left.\begin{aligned} \log 134·62 &= 2·1291096 \\ \log \tan 34° 31' &= \bar{1}·8374049 \end{aligned}\right\} \text{add}$$

$$1·9665145$$

$$\text{next lower} = 1·9665125 = 92579$$

$$\therefore BC = 92·579$$

$$\frac{AB}{AC} = \sec 34° 31'$$

$$\therefore AB = 134·62 \times \sec 34° 31'$$

$$\left.\begin{aligned} \log 134·62 &= 2·1291096 \\ \log \sec 34° 31' &= 0·0840931 \end{aligned}\right\} \text{add}$$

$$2·2132027$$

$$\text{next lower} = 2·2131989 = 16338$$

$$38$$

$$27 = 1$$

$$\therefore AB = 163·381$$

In working out the above example both the functions required should be looked out at the same time, as they are on the same page. This should be done before doing the additions and looking out the next lower: it will save time.

Solution of Scalene Triangles

Rather more work is entailed by the method of solving scalene triangles, because the sides do not represent, nor are they proportional to, the functions of the angles. It is, however, merely a question of remembering formulæ, for the method of using the tables is exactly the same as already described. Before proceeding further we must consider how we are to find the values of functions of angles which contain more than 90°, but less than 180°, as we shall obviously often have angles greater than 90° in scalene triangles, which are triangles having three unequal sides and may be of any shape.

To find the sine of an angle between 90° and 180°.—Look in the tables for the sine of its supplement (i.e. 180° — the angle). This will be the sine of the angle.

Example. Sin 130° = 0·7660444

To find the cosine of an angle between 90° and 180°.—Look in the tables for the cosine of its supplement. Place a minus sign before the figures given and this negative quantity will be the cosine of the angle.

Example. Cos 130° = — 0·6427876

To find the tangent of an angle between 90° and 180°.—Look in the tables for the tangent of its supplement. Place a minus sign before the figures given and this negative quantity will be the tangent of the angle.

Example. Tan 130° = — 1·1917536

To find the cotangent, secant, and cosecant of an angle between 90° and 180°.—Do so by the same rules as those just given for tangent, cosine, and sine respectively.

For the solution of scalene triangles three distinct cases must be considered. The formula for each case depends upon the information given.

The three cases are :—

I. When the given parts are anything except those mentioned in cases II and III.

II. When the only known parts are two sides, and the angle included by those two sides.

III. When the only given parts are the three sides.

The first case is by far the most usual in trigonometrical surveying, the others generally being used only in solving problems connected with inaccessible distances. In any triangle the sine of any one angle divided by the side opposite that angle equals the sine of either of the other angles divided by the side opposite to it. The formula expressed in letters is as follows :—

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

In the triangle ABC (Fig. 137) the big letters denote the angles and the little letters denote the sides opposite. Thus b denotes the side AC, a denotes the side BC, and c denotes the side AB.

In using this formula we select from it such two parts of it as will contain only one unknown quantity. This unknown quantity must be brought to the left of the equation and the given parts to the right. The following examples will make the solution quite clear.

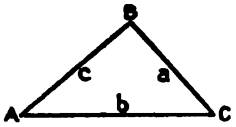


Fig. 137.

Solve the triangle ABC (Fig. 138), the given parts being A = 72° 10′, B = 63° 14′, and a = 30 chains.

(*a*) *Without the use of logs.*

The angle C must equal 180° − (72° 10′ + 63° 14′) = 44° 36′.

If we select from the formula $\frac{\sin A}{a} = \frac{\sin B}{b}$ we shall have only one unknown part—namely, b. Multiply these across and we get—

$$b \sin A = a \sin B$$

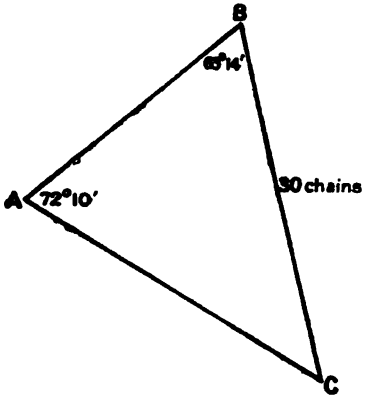


Fig. 138.

We want only the unknown part on the left, therefore divide by sin A and we get—

$$b = \frac{a \sin B}{\sin A}$$

$$\therefore b = \frac{30 \times \sin 63° 14′}{\sin 72° 10′} \qquad \text{(by substitution)}$$

$$\therefore b = \frac{30 \times 0{\cdot}8928480}{0{\cdot}9519514}$$

$$\therefore b = \frac{26{\cdot}78544}{0{\cdot}9519514}$$

$$\therefore b = 28{\cdot}13$$

Now find the side c.

$$\frac{\sin C}{c} = \frac{\sin B}{b}$$

$$\therefore c \sin B = b \sin C \qquad \text{(by cross multiplication)}$$

$$\therefore c = \frac{b \sin C}{\sin B} \text{ (by dividing both sides by sin B)}$$

$$\therefore c = \frac{28{\cdot}13 \times \sin 44° 36'}{\sin 63° 14'}$$

$$\therefore c = \frac{28{\cdot}13 \times 0{\cdot}7021531}{0{\cdot}8928480}$$

$$\therefore C = \underline{22{\cdot}12}$$

(*b*) *With the use of logs.*—It will be noticed that, when using logs in this case, it is not necessary to deduct 10 from the log sin when looking it out in the tables, because it is invariably both added and subtracted in the working, and consequently disappears. *In all other cases however, except Rule* 1, *the* 10 *must be deducted.* In order to prevent confusion we indicate a logarithmic function, which has NOT had the 10 deducted, by a capital L (e.g. L sin A). If the 10 has been deducted we write 'log sin A.' The same example is worked out with the aid of logs thus :—

To find b.

$$b = \frac{a \sin B}{\sin A}$$

$$\therefore \log b = \log a + L \sin B - L \sin A$$

$$\begin{aligned} \log a &= 1{\cdot}4771213 \\ L \sin B &= 9{\cdot}9507775 \\ \hline & 11{\cdot}4278988 \\ L \sin A &= 9{\cdot}9786148 \\ \hline \log b &= 1{\cdot}4492840 \\ \text{Next lower} &= \underline{1{\cdot}4492778} = \underline{28{\cdot}137 = b} \end{aligned}$$

To find c.

$$c = \frac{b \sin C}{\sin B}$$

$$\therefore \log c = \log b + L \sin C - L \sin B$$

$$\begin{aligned} \log b &= 1{\cdot}4492778 \\ L \sin C &= 9{\cdot}8464318 \\ \hline & 11{\cdot}2957096 \\ L \sin B &= 9{\cdot}9507775 \\ \hline \log c &= 1{\cdot}3449321 \\ \text{Next lower} &= \underline{1{\cdot}3449225} = \underline{22{\cdot}127 = c} \end{aligned}$$

CASE II.—A different formula is required in this case, as it will be seen that it is impossible to form an equation with only one unknown from the foregoing formula, when the only information given is the two sides and the included angle.

FORMULA.

Tan of the smaller of the two unknown angles

$$= \frac{\text{(shorter side)} \times \text{(sin of given angle)}}{\text{(longer side)} \pm \text{(shorter side} \times \text{cos of given angle)}}$$

When the given angle is *under* 90° the sign in the denominator is *minus*, and when *over* 90° the sign in the denominator is *plus* (the cos of the supplement being used).

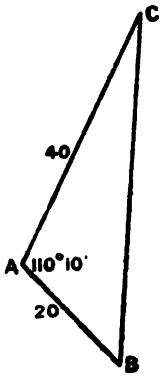


FIG. 139.

The smaller of the two unknown angles is, of course, opposite to the shorter side. The following examples will make the solution clear.

Solve the triangle ABC (Fig. 139), the given parts being—

AB = 20 chains,
AC = 40 chains,
and the angle A = 110° 10′.

(*a*) *Without the use of logs.*

Let A = the included angle.
b = the longer given side.
c = the shorter given side.
C = the smaller of the two unknown angles.

$$\therefore \text{The formula} = \tan C = \frac{c \sin A}{b + c \cos A}$$

$$= \frac{20 \times \sin 110° 10'}{40 + (20 \times \cos 110° 10')}$$

$$= \frac{20 \times 0{\cdot}9386938}{40 + (20 \times 0{\cdot}3447521)}$$

$$= \frac{18{\cdot}7738760}{46{\cdot}8950420}$$

$$= 0{\cdot}4003381$$

$$\therefore C = \underline{21° 49'}$$

The rest of the triangle may be solved by the formula for Case I.

$$B = 180 - (110° 10' + 21° 49') = 48° 1'$$

To find a.

$$\frac{\sin A}{a} = \frac{\sin C}{c}$$

$$\therefore\ a \sin C = c \sin A$$

$$\therefore\ a = \frac{c \sin A}{\sin C}$$

$$= \frac{20 \times \sin 110° 10'}{\sin 21° 49'}$$

$$= \frac{20 \times 0{\cdot}9386938}{0{\cdot}3716379}$$

$$= \frac{18{\cdot}7738760}{0{\cdot}3716379}$$

$$\therefore\ a = 50{\cdot}51$$

Solution: $C = 21° 49'$
$B = 48° 1'$
$a = 50{\cdot}51$ chains.

(*b*) ***With the use of logs.***—It is, of course, a great saving of time to use logs, and the only reason that an example is worked out without the use of logs is to benefit those who have not had the time to study the preceding chapter. It is of the greatest importance that the manner in which the following example is worked out should be implicitly followed. If this is done there will be no difficulty in arriving at a correct solution.

The same example is worked out with the aid of logs thus :—

$$\text{Tan } C = \frac{c \sin A}{b + c \cos A}$$

Start the work with $c \cos A$ ***in the denominator.***

$$\left.\begin{aligned} \log c &= 1{\cdot}3010300 \\ \log \cos A &= \bar{1}{\cdot}5375070 \end{aligned}\right\} \text{add}$$

$$c \cos A = 0{\cdot}8385370$$
$$\text{Next lower} = 0{\cdot}8385343 = 6{\cdot}895$$

Having found the value of $c \cos A = 6{\cdot}895$, add to it b, and so have done with the whole of the denominator.

$$\begin{aligned} b &= 40 \\ c \cos A &= \ 6{\cdot}895 \end{aligned}$$

$$\therefore\ b + c \cos A = 46{\cdot}895$$

Now work out the numerator.

$$\left.\begin{aligned}\log c &= \bar{1}\cdot3010300\\ \log \sin A &= \bar{1}\cdot9725239\end{aligned}\right\}\ \text{add}$$
$$\therefore \log c \sin A = \bar{1}\cdot2735539$$

The value of the numerator is now obtained. From this must be deducted the denominator, but the denominator (46·895) must first be turned into a log, in order to enable us to deduct it from the numerator which is a log.

$$\left.\begin{aligned}\log c \sin A &= 1\cdot2735539\\ \log (b + c\cos A) = \log 46\cdot895 &= 1\cdot6711265\end{aligned}\right\}\ \text{subtract}$$
$$\bar{1}\cdot6024274$$

Now look in the tables in the tangent column for the nearest to $\bar{1}\cdot6024274$, which is $9\cdot6023953 = 21^\circ\,49'$.

$$\therefore C = 21^\circ\,49'$$

And
$$B = 180 - (110^\circ\,10' + 21^\circ\,49')$$
$$= 48^\circ\,1'$$

The rest may be solved by Rule I.

$$a = \frac{c \sin A}{\sin C}$$

$c \sin A$ is already worked out.

$$\left.\begin{aligned}\log c \sin A &= \bar{1}\cdot2735539\\ \log \sin C &= \bar{1}\cdot5701200\end{aligned}\right\}\ \text{subtract}$$
$$1\cdot7034339$$
$$\text{Next lower} = 1\cdot7034290 = 50\cdot516$$
$$\therefore a = 50\cdot516$$

Solution: $C = 21^\circ\,49'$; $B = 48^\circ\,1'$; $a = 50\cdot51$ chains

Case III.—When the three sides are given. This is seldom required in practice, as one would not measure three sides of a triangle for the purpose of finding out the angles. Angles are measured with an instrument to avoid having to measure the sides, as inaccuracy is bound to creep in when long lines have to be chained.

$$\text{Formula} = \text{Tan}\,\frac{A}{2} = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$$

where a, b, c are the three sides, and s = half their sum.

Solve the triangle ABC (Fig. 140), the given parts being as shown.

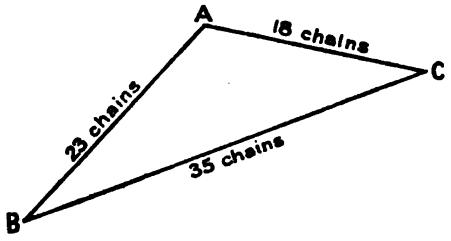


Fig. 140.

(a) *Without the use of logs.*

$$\text{Tan}\,\frac{A}{2} = \sqrt{\frac{(38-18)(38-23)}{38(38-35)}}$$

$$= \sqrt{\frac{20 \times 15}{38 \times 3}},$$

$$= \sqrt{\frac{300}{114}}$$

$$= \sqrt{2{\cdot}6316}$$

$$= 1{\cdot}62222$$

$$\therefore \frac{A}{2} = 58° 21'.$$

$$\therefore A = 116° 42'.$$

The rest of the triangle may be solved by the formula for Case I.

To find C. $$\frac{\sin A}{a} = \frac{\sin C}{c}$$

$$\therefore a \sin C = c \sin A$$

$$\therefore \sin C = \frac{c \sin A}{a}$$

$$\therefore \sin C = \frac{23 \times 0{\cdot}8933714}{35}$$

$$= 0{\cdot}5870726$$

$$\therefore C = 35° 57',$$

and $B = 180 - (116° 42' + 35° 57') = 27° 21'$

(b) With the use of logs.

$$\text{Tan}\ \frac{A}{2} = \sqrt{\frac{20 \times 15}{38 \times 3}}$$

log 20 = 1·3010300		log 38 = 1·5797836
log 15 = 1·1760913		log 3 = 0·4771213
2·4771213	subtract	2·0569049
2·0569049		
2)0·4202164	(divide by 2 to obtain square root)	
0·2101082		

$$\therefore \log \tan \frac{A}{2} = 0{\cdot}2101082$$

$$\therefore \frac{A}{2} = 58^\circ\ 21'$$

$$\therefore A = 116^\circ\ 42'$$

To find B.

$$\frac{\sin A}{a} = \frac{\sin B}{b}$$

$$\therefore a \sin B = b \sin A$$

$$\therefore \sin B = \frac{b \sin A}{a}$$

log b	= 1·2552725
L sin A	= 9·9510320
	11·2063045
log a	= 1·5440680
	9·6622365 = 27° 21′ = B

Solution :

A = 116° 42′
B = 27° 21′
C = 35° 57′

The foregoing notes will be sufficient to enable the surveyor to solve any ordinary problem that he is likely to meet with. It is much better to make use of trigonometry for the solution of the difficulties presented in Chapter II, such as chaining across a wide river, surveying a wood or lake, &c.

For finding the inaccessible heights, such as shown in Fig. 141, proceed as follows :—

Measure the distance AB on the ground. Set up the theodolite

at C and take the angle of elevation ECF. Again set up the theodolite at B and take the angle of elevation EDF. We have now sufficient data to find EF. In the triangle ECD we know the two angles ECD and EDC (EDC = 180° — EDF) and CD which is equal to AB. By the formula for Case I we are able to find

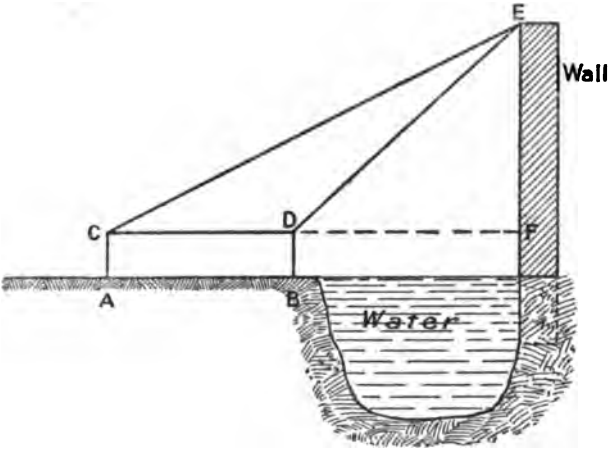


FIG. 141.

out ED. We now have sufficient parts to solve the right-angled triangle EDF—namely, the angles D and F and the side ED. To EF must be added AC for total height.

The Calculation of Areas.—(*a*) *When two sides and the included angle of a triangle are given.*

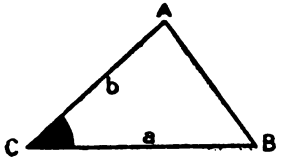


FIG. 142.

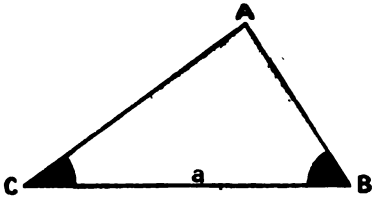


FIG. 143.

$$\text{Area} = \frac{ab \sin C}{2}$$

(*b*) *When one side and the adjacent angles of a triangle are given.*

$$\text{Area} = \frac{a^2 \sin B \sin C}{2 \sin (B + C)}$$

CHAPTER IX

THE BOX SEXTANT

The Box Sextant is a circular brass box, about 3 inches in diameter and 1½ inches deep. Fig. 144 shows the instrument with the cover removed and ready for use.

The instrument is fitted with a cover which, when taken off, is screwed to the bottom of the box, thus making it easier to hold.

T is a telescope for long-distance sights, but it may be dispensed with, and the small eye-hole, where the telescope fits the box, may

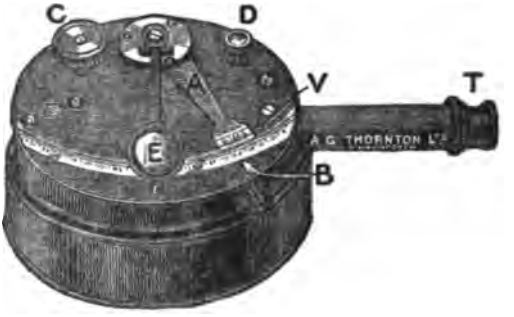


FIG. 144.

be used instead. A is an *Index* arm, with a vernier, V, attached at the end. B is the graduated arc which is 70° in extent, but numbered up to 140°, as will be explained later. C is the milled-head screw which moves the index arm and the index mirror within the box. E is a magnifying glass to enable the vernier, which reads to minutes, to be seen distinctly. D is a key screwed into the top of the box; it is detachable and used for adjusting the instrument. Dark glasses are fitted within the box: they may be interposed between the eye and the sun, when observation to the latter is required to be made. Two mirrors are placed within the box, the index glass which is attached to the index arm, and moves simultaneously with it; and the horizon glass which is fixed and has only its upper half silvered.

The Principle of the Box Sextant.—The box sextant is a reflecting

instrument similar to the optical square and apomecometer, which have been already described. It is consequently governed by the same laws. The principle of all reflecting instruments is that, '*If there are two plane mirrors whose reflecting surfaces make a given angle with each other, and a ray of light, in a plane perpendicular to the planes of both mirrors, is reflected from both successively, its direction after the second reflection, makes with its original direction an angle which is twice the angle made by the mirrors with each other.*' As the angle measured between the two mirrors is equal to half the actual angle between the two objects, the arc of 70° is divided into 140°.

Holding the instrument in the left hand, the left-hand object X (see Fig. 145) is observed by direct vision through the lower half of the horizon glass. Turn the milled-head screw C (Fig. 144) and so move the index glass until the other object Y is seen reflected, from the index glass, in the upper half of the horizon glass, exactly coincident with X. Then the angle IEH is double the angle IAH. Hence the graduation of the arc as explained. The right hand should be manipulated in such a way that the arm does not cover the opening in the side of the box and so prevent the reflection of the object Y.

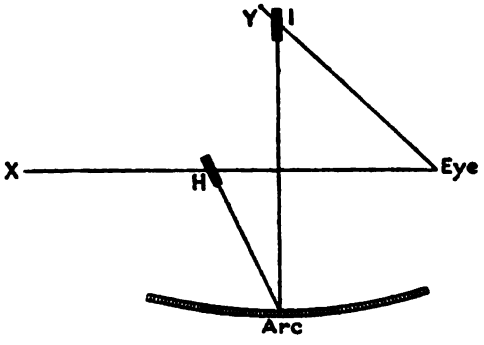


FIG. 145.

Index Error.—When the two mirrors are parallel to each other the vernier ought to read 0. The index error should be noted before measuring angles. It will be seen that the graduations of the arc continue to the left of 0. This portion is called the '*arc of excess.*' If the error is on this side of 0, it is called *index error off*, and it is obvious that angles read in this case will be too small; if the error is to the right of 0 it is called *index error on*, and angles read in this case will be too large. Accordingly the index error off is to be added, and the index error on is to be subtracted.

Adjustment.—Now when the instrument is in adjustment both mirrors are at right angles to the top of the box and parallel to each other when the vernier reads 0.

The index glass is permanently fixed by the maker, but the horizon glass is adjusted thus:—Set the reading exactly to 0 and observe some well-defined object *over half a mile distant.* If the instrument is in adjustment, the object observed and its reflected image will exactly coincide. But if the instrument is out of adjustment they will appear separated. They may appear separated thus °, or thus, ∘∘ or thus ₀°. Supposing they are separated both

horizontally and vertically (₀°). Unscrew the key D which is attached to the instrument as shown in Fig. 144 and fit it to the square head on the top of the box and bring the object and its image level with one another, thus ∞. Now to make the object and image coincide apply the key to the square head at side of the box. The instrument has then been adjusted. It is important that the object should be fully half a mile away when making this adjustment. The sun may be observed for the purpose.

Its use.—The box sextant is very useful for the approximate measurement of angles, both horizontally and vertically. It is best employed as an aid to a chain survey and instead of checking each triangle by measuring a tie line. Surveys made with it, when triangles are not used, are only approximately accurate.

Disadvantages of the Box Sextant.—1. As the arc of 70° is divided into 140° any error of observation is doubled.

2. In measuring angles when the two objects are not on a level with the eye, the oblique angle is obtained which must be reduced to its horizontal projection by the proper formula before it is made use of.

3. Angles greater than 110° cannot be observed with it, as the angle of incidence is too great to allow proper reflection. This difficulty may be overcome, however, by interposing an intermediate object and dividing the angle into two smaller ones.

4. Parallax. The more distant the object sighted to the less is the error due to parallax. It will minimise the error if the more distant object is sighted to by reflection. If *both* objects are near, it is better to take some point which is in line with one of them at a distance away, and to observe this point by reflection and the near object by direct vision.

Method of plotting a small survey made with the aid of the box sextant.—A small area will suffice to show the best way of plotting angles with the protractor. Fig. 146 is the survey of a small enclosure wherein it was found impossible to run diagonal lines to form a base for triangulation. The sides were measured with the chain and the included angles with the box sextant. The sum of the angles taken should be equal to twice as many right angles as the figure has sides *minus* four right angles: this fact enables us to check the result of our observations.

AB is the base line. We must first obtain the bearings of the rest of the lines from the base line. To do this add together all the interior angles.

The interior angle at	A =	86° 30′	= the bearing of	AD	
Add ,,	,, D =	94° 30′			
		181° 00′	= ,,	,,	DC
Add ,,	,, C =	74° 30′			
		255° 30′	= ,,	,,	CB
Add ,,	,, B =	104° 30′			
		360° 00′			

Now place the protractor (shown in Fig. 65, Chapter IV) on the paper so that the point A is its centre, and by means of the arm prick off the bearings as shown. The protractor can now be taken off. By adopting this method the protracting of each angle separately is avoided and consequently the error in any one angle is not carried through the rest of the work : also the marking of the paper through placing the pointed feet of the protractor upon it in several places is similarly prevented.

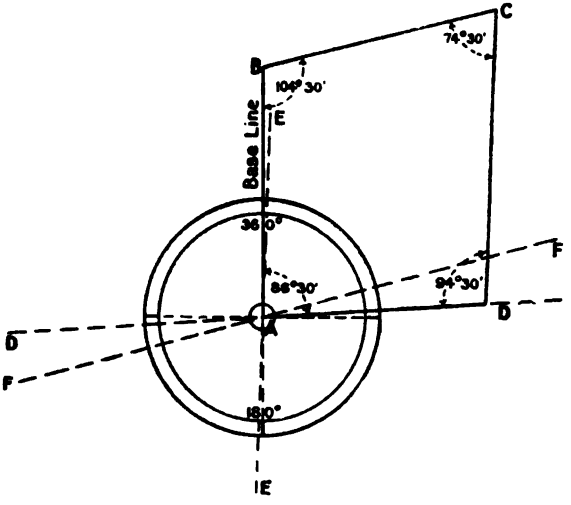


FIG. 146.

Now draw the line AB with the scale selected for the plot to its measured length. Next draw AD similarly and bearing 86° 30′. Now draw DC with the parallel rule parallel to AE and mark off the point C with the scale according to its length, and lastly CB parallel to AF. The work is checked by CB closing on the point B if the measurements have all been correctly made.

If when adding the interior angles together they sum to more than 360°, then subtract 360°.

CHAPTER X

THE PLANE TABLE

THE Plane Table is a simple instrument, which is chiefly useful for filling in the detail of a survey, but also for making original surveys. It consists of a drawing board which is generally 23″ × 16″, though larger sizes are obtainable, mounted on a tripod in such a way that it may be turned horizontally, levelled, set in any direction and clamped. In addition a trough compass, a spirit level, a sight rule or alidade, a sheet of drawing paper, pins, pencil, india-rubber, and plotting scale are required for its use.

Fig. 147 shows a plane table with sliding adjustable tripod, revolving motion, fitted with clamped board size 23″ × 16″; brass alidade 18″, A, with divided edge and removable sights; telescope with level and graduated arc; trough compass B; and spirit level C.

It is not necessary that the alidade should be fitted with a telescope as shown in Fig. 147, but it is very useful for plotting in detail by single rays observed to a staff with stadia points, as explained in the chapter on Tacheometry. In the following notes the use of the telescope is dispensed with, an ordinary sight vane only being used.

The use of the Plane Table.—When starting a survey with the Plane Table and no fixed points have already been determined it is first necessary to measure a base line. This base line should be about the centre of the survey, and the longer the better within reason. It should be as nearly horizontal as possible. Set up the table over one end of this base line firmly upon its tripod; cut a sheet of drawing paper so as to have an overlap of about 2 inches all round the table; damp the paper, turn down the edges and fasten them underneath the board with pins. Now carefully level the table by means of the spirit level. Draw a line on the paper to scale to represent the base line on the ground. Place the sight rule against this line and turn the table until the sights come on to the other end of the base. Now clamp the table. Thus the line drawn between the two stations on the table is parallel to the line

between the stations on the ground. This is called *orienting* the table and is the most important point to be observed in Plane Table surveying, so as to secure accuracy. When the table has been oriented, the compass should be placed in one corner of the table and turned until the needle is pointing north. It is convenient to draw a pencil line round the box to mark the position of the compass for future reference. It should be noted that the point on the table which represents the station and not the centre of the table should be over the station on the ground. The table may be placed in the

FIG. 147.

required position near enough by dropping a stone from the corresponding point beneath the table, or by using a plummet.

We are now ready for fixing points by intersection. (See Fig. 148.) AB is the base line and *ab* the base line on paper. Place a pin in the table at A, hold the sight rule against the pin and pivot it until it is directed on to the station C. Now draw a ray along the edge of the sight rule as shown. Do the same for the rest of the stations D, E, F. These rays give the direction of the stations C, D, E, F from A. Now move the table and set it up at the other end of the base B. Carefully orient it and draw rays from *b* to all the stations as before. The intersections of these rays give the exact position to scale of the stations C, D, E, F. No important station should be intersected from the base if it is at a much greater

distance from either end than the length of the base; nor if it lies much outside of a perpendicular to the base at either end of it. As in ordinary chain surveying, the triangles should be as well conditioned as possible. The table may now be shifted to another well-fixed station and the same process gone through until the survey is completed.

Checking the work.—The work should be frequently checked by sighting on to preceding stations from say every third station. Further checks may be made by measuring the distance between two stations on the ground and comparing it with the plotted

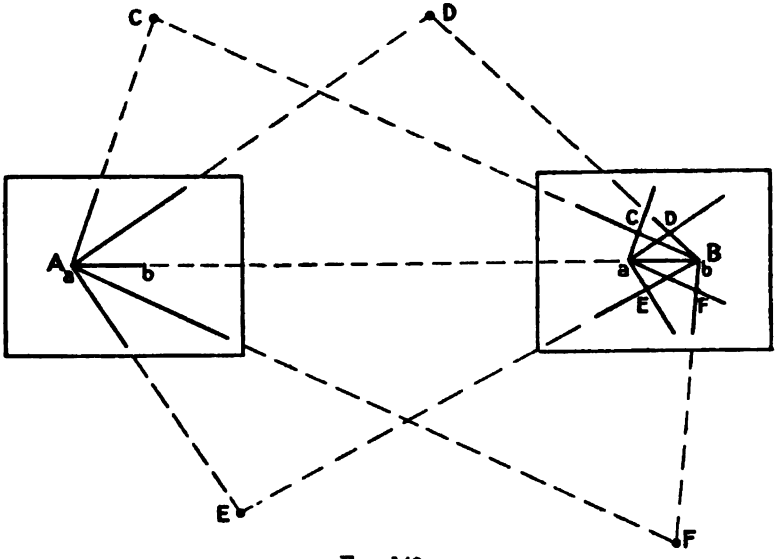


FIG. 148.

distance on the plan; and by setting up the table at any station and sighting on to other stations.

To continue the survey on a fresh sheet.—The following note has been taken from 'Hints to Travellers' published by the Royal Geographical Society. Draw a line through the farthest point fixed from the last station. Take the sheet off the table and fix another on, drawing a line upon it in a part most convenient for the work; then cut the sheet just taken off, by the line drawn on it. Apply this edge to the line on the new sheet, and as they lie in that position continue the lines from the other sheet on the new paper, and prick through the positions of as many stations that have been fixed on the old sheet as you conveniently can. If the positions of three fixed points are transferred to the new sheet,

the place of a new station can be found. On each new sheet the magnetic N. and S. line should be drawn.

To 'set' a plane table.—By this is meant placing the table in such a position that the plan on the board coincides with the ground it represents. There are several ways of doing this.

(*a*) When the spot is marked on the plan, choose any distant point which can be identified in Nature and which is also shown on the plan. Now place the alidade along a line which joins the position of the observer and the spot shown on the plan. Turn the board until the same spot in Nature is observed in alignment. (See Fig. 149.) This is a very useful method of checking maps in the field. Having thus 'set' the table, all the other salient points can be sighted off in a similar manner and their positions checked.

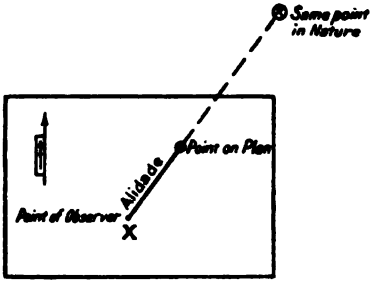


FIG. 149.

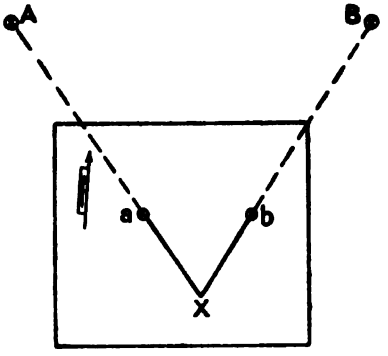


FIG. 150.

(*b*) When it is impossible to identify the spot on the plan, place the magnetic compass on the board in the rectangular space and turn the board until the compass points N. The table can now be set by *resection* on any two fixed points.

Example.—A and B (Fig. 150) are two points in Nature which can be identified, and which are represented on the plan by *a* and *b*. X is the unknown point which is required to be fixed. First set the table as explained, by means of the compass, and then clamp it. Put a pin in the board at *a*, place the alidade against the pin and pivot it until it is aligned on to A in Nature. Having obtained exact alignment draw a line along the edge of the alidade backwards to the observer. Now put the pin in at *b*, sight on to B as before, and draw a line along the edge of the alidade backwards to the observer. Where these lines intersect is the position of X. It is usual in cases of importance to check this position by using a third point. The line drawn from the third

point should also pass through X, if it does not it will form what is termed a *triangle of error*. When there is a triangle of error it is generally due to incorrect orientation of the table, unless the positions of the points chosen have been incorrectly determined.

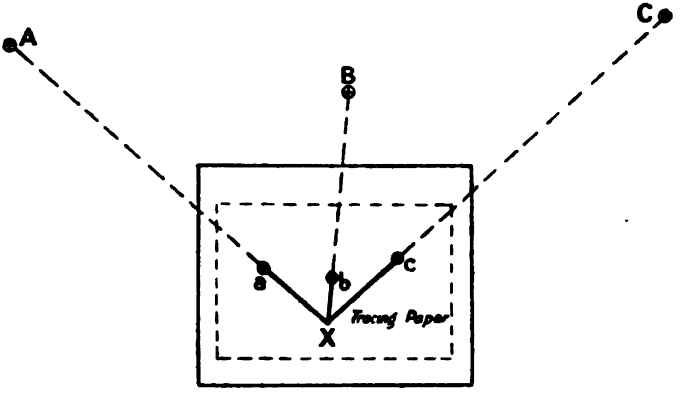


FIG. 151.

When a compass is not available the usual methods of determining one's position are—

(*a*) *By Adjustment.*—When using this method three points shown on the plan must be capable of identification in Nature.

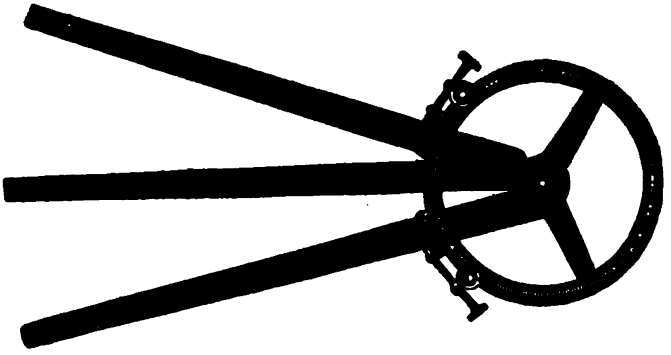


FIG. 152.

It is also necessary that the three points chosen should not be on the circumference of the circle passing through the position of the observer; or in other words the middle point selected should be the nearest.

Set up the table and pin a piece of tracing paper firmly on to the board. Put in a pin at any convenient point X (Fig. 151). Now draw lines from X to the three fixed points A, B, C. It will be seen that we have now practically plotted the two angles AXB, BXC, so that, having removed the tracing paper and applied it to the plan, we can fix the point X by moving the tracing about until the lines XA, XB, XC pass through the points *a*, *b*, *c* on the sketch.

Now if we place the alidade along any one of the lines *xa*, *xb*, *xc*, and turn the table until it is aligned on to the point chosen, we can 'set' the table.

A station pointer may be used instead of tracing-paper and plotting. The station pointer consists of a circular protractor (Fig. 152) numbered from 0° to 180° each way, and having three arms, one of which is fixed. When using it the two movable arms are sighted to the points selected and set to the angles required.

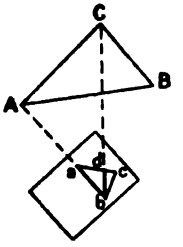


Fig. 153.

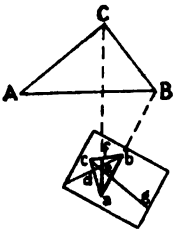


Fig. 154.

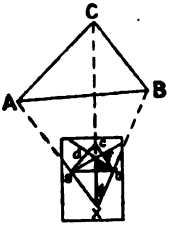


Fig. 155.

The instrument is then moved over the points on the map until the arms pass through them. The centre of the circle marks the observer's position.

(*b*) *By the Three-point Problem*, which is the method of fixing the position of an unknown point from three known points. A, B, C are the three known points. Set up the table at the point whose position is required. Lay the sight rule along *ba* (Fig. 153) and turn the table until aligned on to A. Clamp the table, place the alidade at *b*, sight on to C and draw the line *bd*.

Unclamp the table. Lay the alidade along *ab* and turn the table until aligned on to B (Fig. 154). Clamp the table, place the alidade at *a*, sight on to C and draw the line *af*C cutting *bd* in *e*; and from *c* through *e* draw the line *ceg*. Unclamp the table. Lay the sight rule along the line *ceg* and turn the table until aligned on to C (Fig. 155). Clamp, and the table is 'set.'

To find the position of X, place the alidade at *a* and sight on to A, then draw the line A*a*X until it cuts the line *ceg*. The point of intersection is the required spot. Check the work by drawing B*b*X, in a similar manner.

The problem may be solved geometrically in the following manner (Fig. 156):—

Join AB. Make the angle BAE equal to the angle ADB. Draw AF at right angles to AE. Bisect AB at H. Draw HK at right angles to AB meeting AF at K. With centre K and radius KA describe the circle ABD. Now D may be anywhere on the arc ADB, and the angle ADB will be the same. Join BC. Make the angle BCL equal to the angle BDC. Draw CM at right angles

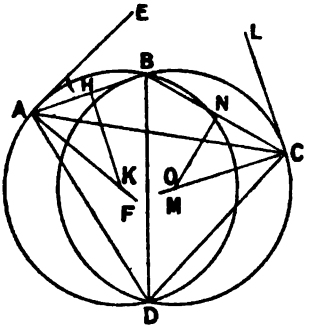


Fig. 156.

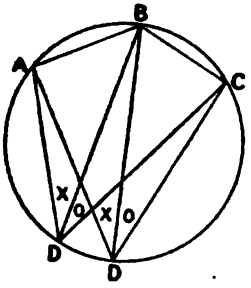


Fig. 157.

to CL. Bisect BC at N. Draw NO at right angles to BC, meeting CM at O. Then with centre O and radius OC describe the circle BDC, and the point at which the two circles cut one another will be the required point D.

It will be seen that the point D is *indeterminate* when C is on the circumference of the circle ABD, that is to say, when the three known points and also the unknown point are on the circumference of a circle.

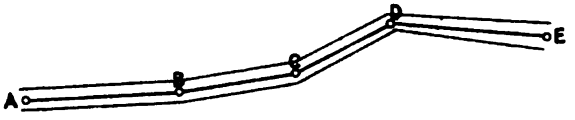


Fig. 158.

The chords AB and BC subtend equal angles at any point on the same arc—Euclid, III. 21. (See Fig. 157.)

Traversing with the Plane Table.—This may be done in two ways: (1) With the compass; (2) By back and forward rays. When *Method* 1 is adopted the table is 'set' at each station by the compass.

Example.—ABCDE represents a road through closed country (Fig. 158). The table is set up at A and oriented. AB is measured

on the ground and drawn to scale on the paper : offsets are taken when required and also laid down to scale. The table is then transferred to B. At B it is again set up and oriented and the work proceeds as before. This method is most usual when the country is not open.

Method 2 is best for open country, though the two may be combined with more satisfactory results. Checks are obtained by sighting on to distant objects from time to time. When traversing by back and forward rays, however, any error which is made in the first direction will increase considerably as the work proceeds, with every subsequent direction. By the compass method this is not the case as the error is just the same at the end as it was when first made.

To traverse by back and forward rays the table is set up at A (Fig. 158), AB is measured and drawn to scale on the paper, and the detail is sketched in by means of offsets perpendicular to the forward ray. The table is then transferred to B and turned until the alidade is aligned on to A the back station. It is then clamped and the table is set by the back ray. Now direct the alidade on to station C, draw in the forward ray, and proceed as before. Any more distant object which it is required to show on the plan can be fixed by means of intersecting rays from two or three stations.

Single rays will suffice to fix points near the station. The alidade is aligned on to the object to be shown, a ray is shot off along its edge, measured on the ground, and drawn in to scale on the paper. Further notes on traversing are given in Chapter XII.

CHAPTER XI

THE THEODOLITE

WHEN surveying land covered with buildings or woods, &c., to such an extent that check lines cannot be measured, it is necessary to measure angles. Angles are measured in surveying for two purposes: (1) To fix the direction of survey lines already measured; (2) To calculate by trigonometry the lengths of lines. The taking of the angles should be done after the chaining is finished. Pegs are inserted in the ground where the surveying poles stood which marked the stations and the theodolite is set up over these station pegs, the angles are read and entered in the field book as shown in Fig. 159.

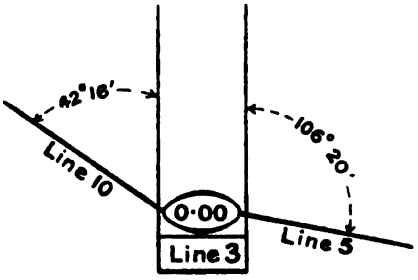


FIG. 159.

To understand the theodolite practical instruction is essential, and this chapter can only be of value if read after a certain amount of practical experience in the manipulation of the instrument.

Fig. 160 shows Messrs. Thornton's 'Ardley' Transit theodolite on its tripod stand. It is fitted with a dial compass; pierced illuminated axis lantern; striding bubble; improved locking plates and three-screw adjustment, with shifting centre. The vernier reads to one minute. A 5-inch theodolite with 9½-inch telescope and tripod stand, of similar pattern, costs about £32. It can be fitted with any of the diaphragms shown in Fig. 95, Chapter VI.

Instruments are called according to the diameter of their horizontal limbs. Thus a 5-inch theodolite is one which has a horizontal circle of 5 inches in diameter.

Description.—AB is a telescope which consists of two tubes one sliding inside the other. At the A end is the *object glass*, which inverts the image of the object observed, and at the B end is the *eye-piece* which magnifies the inverted image; C is the bubble tube fixed to the telescope by the capstan-screws through which

it may be set parallel to the line of collimation; D is the horizontal or transit axis; E and F are the supports which are of such a height that the telescope may turn completely round on its axis or as it is called, 'transit'; G is the vertical circle or limb or face, and H and I are microscopes for reading the vernier; J is the compass; K is the upper or vernier plate and L the lower or horizontal plate; these plates are concentric and are called the horizontal limb of the instrument; M is a clamping screw for clamping the upper plate and N the slow-motion screw for giving accurate bisection of the object; O is the vertical axis round which is a collar that may be tightened by a clamping screw, thus preventing the instrument from turning round; Q is the slow-motion screw for obtaining accurate bisection; R is the tribrach and S, S, S the levelling screws by means of which the horizontal limb is set truly horizontal; T is the tripod stand.

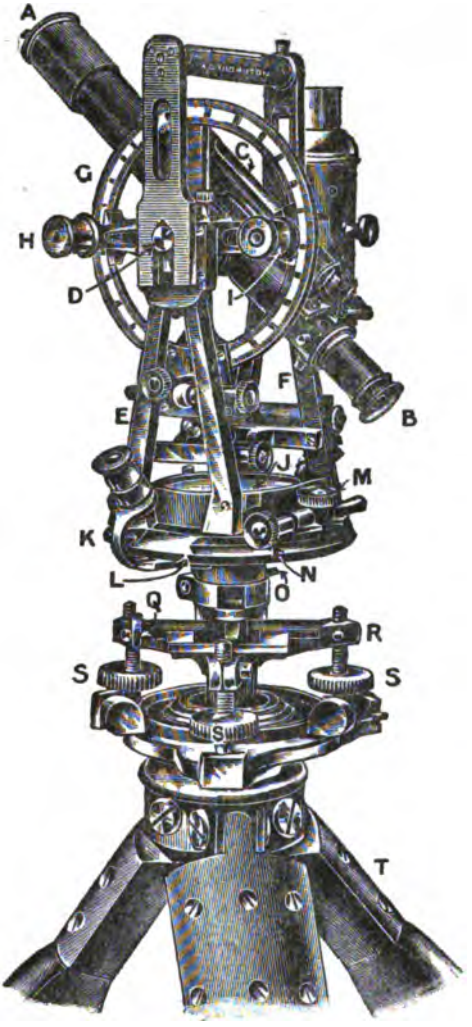


FIG. 160.

Figs. 161 and 162 show the instrument in greater detail. In Fig. 161 will be seen a hook from which a plumb-bob is suspended to enable the instrument to be correctly set up over the station pegs. For ordinary surveying this instrument is the most useful type. Other types are the Everest and the Y.

The Everest differs from the Transit in that it is lighter and more easy to carry; the telescope cannot be completely revolved on its horizontal axis; it has not a complete vertical circle; and

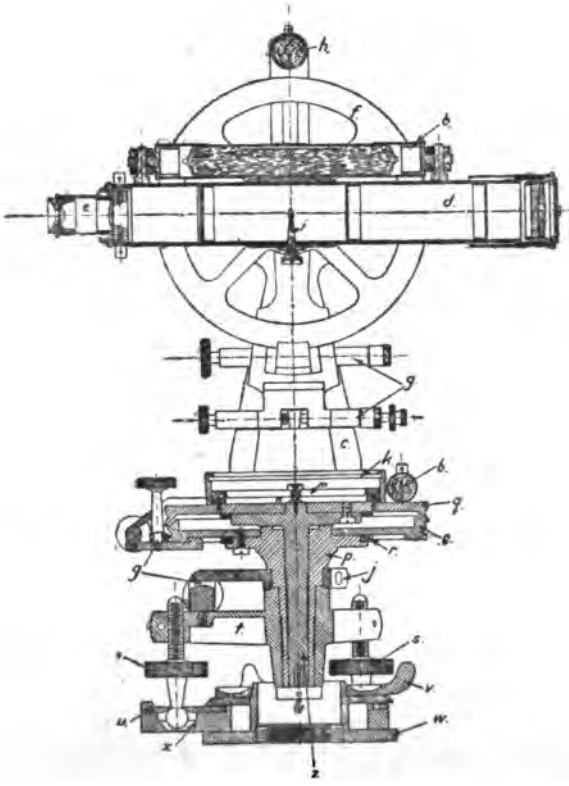


FIG. 161.

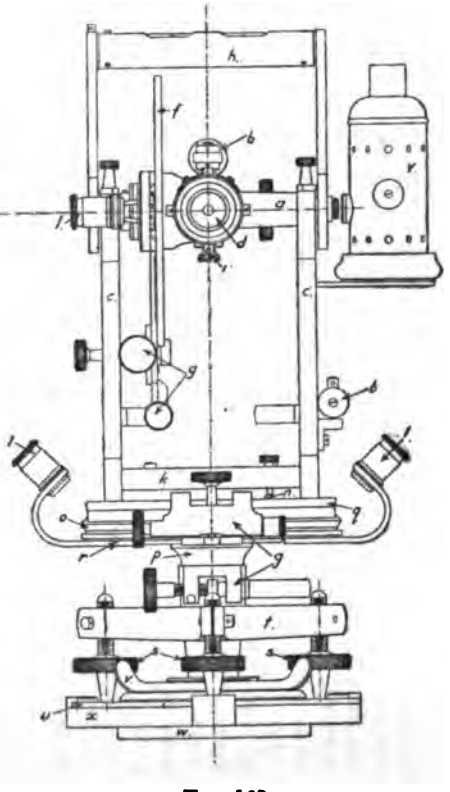


FIG. 162.

REFERENCES

(*a*) Transit Axis
(*b*) Bubbles
(*c*, *c'*) Standards
(*d*) Telescope
(*e*) Eyepiece
(*f*) Vertical Circle
(*g*) Clamp & Spring Tangents
(*h*) Striding Level
(*i*) Reflector for Illuminated Axis
(*j*) Axis Collar Clamp
(*k*) Compass Box
(*l*) Readers
(*m*) Magnetic Needle
(*n*) Needle Lifter
(*o*) Graduated Limb
(*p*) Body Piece
(*q*) Cover Plate
(*r*) Ring to carry Readers
(*s*) Plate Screws
(*t*) Tribrach
(*u*) Locking Plate
(*v*) Clamp to Shifting Centre
(*w*) Bottom Plate
(*x*) Shifting Centre
(*y*) Lamp
(*z*) Central Vertical Axis

the bubble tube is fixed to the vernier arm instead of to the telescope.

In the Y theodolite the telescope is supported in two Y's at the end of a bar which is fixed at right angles to the horizontal axis, and on top of the vertical limb. It possesses only a semicircle. (See Fig. 163.)

To Measure a Horizontal Angle.—1. Set up the instrument exactly over the station by means of the plummet which should hang exactly over the centre of the station peg.

2. Clamp the horizontal plate and unclamp the horizontal vernier plate; turn the latter until the arrow of the vernier coincides exactly with the 360° on the horizontal limb, accurate bisection being obtained by means of the slow-motion screw and magnifying glass.

3. Level the instrument by means of the foot-screws, as explained in the chapter on Levelling, until the bubble remains always in the centre of its run.

4. Unclamp the *whole* instrument and direct the telescope on to the *left-hand object* until the latter is approximately bisected. Now clamp and obtain accurate bisection by means of the slow-motion screw.

FIG. 163.

5. Unclamp the *horizontal vernier plate* and direct the telescope on to the next object until it is approximately bisected. Clamp and obtain accurate bisection by means of the *slow-motion screw attached to the vernier plate.*

6. The angle subtended at the station over which the theodolite is set up by the two objects may now be read from the horizontal limb and verniers, and their mean taken as the correct horizontal angle.

To Measure a Vertical Angle.—1. Set up the instrument over the station, and level the horizontal plates as before.

2. Set the vertical verniers to read zero, and then level the arc by bringing the vertical arc level bubble into the centre of its run by means of the antagonising screws.

3. Now direct the telescope to the object whose angle of elevation or depression is required. Obtain accurate bisection, after clamping with the vertical clamp, by means of the vertical slow-motion screw.

4. The vertical angle may now be read from the vertical verniers, and their mean taken as the correct vertical angle.

The most important points to be observed in angular measurements are *accurate centreing* of the instrument over the station and *correct bisection of the objects*. To obtain accurate centreing by means of the plummet requires care and, unless one hits it off approximately at the first setting up of the instrument on its tripod, also time. Some instruments have centreing plates which allow for a movement of about 3 inches each way and make accurate centreing an easy matter, but when there are not centreing plates, the plumb-bob must be centred by shifting the legs only, and pressing them into the ground one at a time, until the bob is exactly over the centre of the station peg. The angle should always be read off on each vernier and the mean taken, so as to minimise errors of graduation of the arc.

Changing Face.—When great accuracy is required—in fact one might say on all occasions, and especially when taking vertical angles—every angle should be observed with what is known as *changed face*, and the mean of the two observations taken. When the observer is standing at the eye end of the telescope of a theodolite and the vertical limb is on his left hand the instrument is then said to be at *face left*, and when in a similar position the limb is on his right hand, the instrument is at *face right*.

To Change Face.—After observing the angle with the instrument at face left (F.L.), next observe the same angle with the instrument at face right (F.R.). To do this move the left-hand or A vernier through 180° in azimuth so that the object-glass occupies the position which was occupied by the eye-piece. Now revolve the telescope vertically through 180° on its horizontal axis, and the vertical limb will be on the right hand and the instrument at F.R. The vernier which reads from 0 is called the A vernier, and that which reads from 180° is called the B vernier.

By using both faces of the instrument most errors are eliminated, such as the error of horizontal collimation and errors due to the transit axis not being properly level.

Errors due to eccentricity, i.e. through the vertical axis not being exactly concentric with the upper and lower plates, are eliminated by reading both verniers.

Errors due to imperfect graduation are eliminated by measuring the angle several times on different parts of the graduated limb.

When observing to a pole always bisect the *bottom* of the pole.

Repetition.—When the greatest accuracy is required what is known as repetition should be adopted. It is carried out as follows: Clamp the vernier plate to zero and direct the telescope on to the left-hand object. Clamp the lower plate and accurately bisect the object by means of the *lower* slow-motion screw. Read both verniers.

Unclamp the vernier plate and accurately bisect the right-hand object. Read both verniers and the mean of the two readings is the angle required. Having done this unclamp the lower plate and again carefully bisect the left-hand object. Unclamp the vernier plate and accurately bisect the right-hand object once more. The readings on the verniers should now be double the first readings obtained. This operation may be repeated as many times as desired, and is generally performed once round the circle.

If we divide the difference between the first and last readings by the number of times the angle is repeated, we shall obtain the required angle.

The following is an example of how the readings may be recorded:

Object	A Vernier	B Vernier	Mean
Back . .	0° 0′	180° 1′	0° 0′ 30″
Fore . .	36° 10′	216° 11′	
Fore . .	72° 21′	252° 22′	
Fore . .	108° 31′	288° 32′	108° 31′ 30″
		3	108° 31′ 0″
		Mean angle =	36° 10′ 20″

The same angles should now be taken with changed face and the mean of the two results will be the correct angle. With regard to this method it may be observed that although the errors due to imperfect graduation are minimised, the errors due to imperfect observation are accumulated; and at the same time any errors which are due to instability of clamping and tangent screws are introduced.

Reiteration.—This is the most accurate method of taking an angle, but is only resorted to in important work on a large scale. It is performed as follows: With the A vernier clamped to zero the telescope is directed so as to bisect some selected object, called the R.O. or referring object. All the verniers are then read. Next unclamp the vernier plate and bisect each of the objects to be observed consecutively, and return to the R.O. The angles read on each vernier are booked.

Now, if the theodolite has two or four verniers start afresh with the A vernier reading 90° or if three verniers 120°, and proceed as before. Continue with the A vernier reading 180° and 270°, when there are two or four verniers, or 240°, when three.

The work should now be repeated with changed face, and the mean of the observations taken.

In ordinary work it is not necessary to adopt the above-mentioned methods which are long and troublesome; it will be sufficient merely to take two observations to each object, one with F.R., and one with F.L., and to enter in the horizontal angle book the readings of each vernier.

FORM OF BOOK

Observed Object	Face	A Vernier	B Vernier	Means of Verniers	Angles
	L R				

Surveying with the Theodolite.—When making small surveys it is only necessary to observe the angles formed by the outside survey lines to enable the figure to be plotted. The work may be checked by adding together the degrees contained in these angles, the total of which should equal twice as many right angles as the figure has sides *minus* four right angles.

When the base line divides the estate into two portions, it is better to take the angles which the external lines make with it at either end, so that there may be two independent figures when checking the angles. In large surveys it is advisable to take all angles formed by the base lines with one another, and any other angles which will supplement check lines.

The chief advantage of using a theodolite is that the trouble of measuring tie lines is obviated, as is also the measurement of those lines which in a chain survey are only measured to enable the work to be plotted.

When making a survey with the theodolite, therefore, we should observe all those angles which are requisite for the plotting of the work, and in addition angles which will serve as a check.

When observing the angles of a triangle so as to enable the unmeasured sides to be calculated it is necessary to take all three angles so that there may be a check on the observations. The three angles should, of course, sum to 180°. Any very small error which results may be distributed equally over the three angles before they are used in computation. Well-conditioned triangles should always be laid down.

In the case of the large triangles used in geodetic surveys the three angles will sum to more than 180° owing to the fact that the triangle is spherical due to the curvature of the earth. This is termed the *spherical excess*, and a correction must be applied to the angles observed. Sometimes the theodolite cannot be set up over the point observed to. In this case it is set up as near as possible over what is termed a *satellite station*, and a reduction is

applied to the observed angle in order to obtain the correct angle at the centre. Satellite stations should be avoided as much as possible.

The Survey of a Country.—The country is first divided into a number of large triangles whose sides may be of any length from 10 to 100 miles. A *base line* which is one of the sides of a principal triangle is measured with the utmost care. Such a base line is selected on a level piece of country. All the angles of the triangles are next observed.

The great triangles into which the country is first divided are called the *primary triangulation*. The primary triangles are next divided into smaller ones, and this is called the *secondary triangulation*. The secondary triangles are then further divided into tertiary triangles, called the *tertiary triangulation*. The triangles are now of a size which may be dealt with in the ordinary way.

The base line is the only line actually measured, all the rest being calculated, but sides may be measured here and there at considerable distances, to act as checks or *bases of verification*.

The survey of the United Kingdom may be taken as an example. Two principal bases were measured by means of General Colby's compensated bars, one on Salisbury Plain 6·97 miles long, the other near and partly across Lough Foyle 7·89 miles long. The length of the latter base was calculated by a triangulation carried from the Salisbury Plain base, and the difference between the computed and measured length of the Lough Foyle base was only 5 inches, on account of which a correction of 2½ inches was made.

The triangulation consisted of a network of triangles over the entire country, the primary triangles having sides from 30 to 111 miles in length. The angles were measured with four large theodolites, two 3 feet in diameter, one 2 feet, and one 18 inches. By means of the secondary triangulation the long sides of the principal triangulation were reduced to lengths of 5 miles. The angles were measured by a 12-inch theodolite. The 5-mile sides of the secondary triangulation were reduced by means of the tertiary triangulation to lengths of 1 mile or less. In towns the station points were sometimes within as short a distance as 1 furlong. The angles were measured with 7- and 5-inch theodolites. The traversing was done to close on the tertiary triangles, and the filling in and detail closed on the traversing. The area of each field was computed from the plotted detail. I am indebted for the above information on the Ordnance Survey of the United Kingdom to N. Mitra's 'Manual of Surveying.'

Adjustments of the Transit Theodolite.—These may be divided into two classes—namely, temporary and permanent. The former must be attended to every time the instrument is used, but the latter are not often required, unless the instrument has been badly handled. When angles are properly taken with 'changed face' the error, if any, which is due to the instrument being out of adjustment, is negligible for ordinary work.

In any case, the temporary adjustments must be very carefully made before testing the permanent adjustments.

The **temporary adjustments** are :—

1. *The 'setting up' of the instrument* over the station peg, which has been already described.

2. *The 'levelling up' of the instrument.*—This is effected by making the vernier plate horizontal by means of the bubble tubes as described for the Dumpy Level. If the bubbles of the levels, after being levelled by the foot-screws, retain their centres during a rotation through 180° the instrument is properly 'levelled up.'

3. *The prevention of parallax.*—This is done in a manner similar to that described for the Dumpy Level.

The **permanent adjustments** are :—

1. *To set the levels of the horizontal limb parallel to the upper plate, and perpendicular to the vertical axis of the instrument.*—Set up the instrument nearly level by the legs of the tripod. Place one of the levels parallel to two of the foot-screws and by them bring the bubble to the centre of its run. By the third foot-screw bring the bubble of the other level to the centre of its run. If the bubbles retain their centres on turning the telescope half round (the upper and lower plates should be clamped together during this adjustment) the bubble tubes are parallel to the upper plate. If they do not retain their centres, correct half the error by the foot-screws and half by the capstan-headed screws at the ends of the levels. Repeat till perfect.

2. *Adjustment of the supports of the horizontal axis of the telescope.*—After the instrument has been levelled up the horizontal axis of the telescope should be truly level so that the telescope may revolve in a truly vertical plane. This adjustment may be carried out in two ways: (*a*) When there is no striding level; (*b*) When a striding level is attached (see *h*, Fig. 162).

(*a*) *Without a striding level.*—Set up the instrument at a distance of (say) 50 feet from some lofty object such as a church tower. Level carefully and sight on to some point at the top of the object, carefully bisecting it by the cross-hairs. Lower the telescope and make a mark at the bottom of the object where the cross-hairs intersect. Now revolve the telescope through 180°, transit it, and again sight on to the point at the top of the object. Again lower the telescope and note if the cross-hairs exactly intersect the lower mark. If they do, the transit axis is truly horizontal; but if not, correct half the error by means of the capstan-headed nuts which are situated just below one of the Y bearings. Repeat till perfect.

(*b*) *With a striding level.*—The striding level is a spirit level with two upright legs equal in length (see *h*, Fig. 162) fixed to the ends of the bubble tube. It is capable of being fixed on the transit axis for the purpose of testing its horizontality. Level the instrument by means of the bubble tubes on the vernier plate and see that this adjustment is correct.

Open the cleats which keep the ends of the transit axis in its bearings, and erect the striding level on the axis over the bearings. Reverse the striding level and carefully observe it. If the bubble does not remain in the centre of its run, it must be made to do so by turning the capstan nuts at the bottom of the adjustable Y until it is quite correct. When the adjustment has been made for one position the striding level bubble should remain steady during a complete revolution of the instrument. The axis, which is set right by the makers, is not likely to change, and consequently the adjustment has very seldom to be made.

2A. *Adjustment of Telescope Bubble, or Bubble on Vernier Arm.*—Set vernier on circle to zero, by the two screws on T carrying piece, bring level to centre of its run, reverse telescope exactly 180°. If bubble has moved, correct half of the error between capstan screws holding level tube and T antagonising screws attached to vernier arm.

3. *Adjustments for Lines of Collimation.*—(*a*) *For vertical line*:—Before commencing this adjustment all level bubbles should be tested true on reversion after setting up. Direct telescope on a distant point or line (as far off as possible), clamp both horizontal circle and main centre. Lift telescope bodily from understructure, and reverse pivots in their bearings, end for end. Transit telescope 180°, and in new position note whether vertical line still cuts point selected. Adjust for any error by means of the two horizontal diaphragm screws.

(*b*) *For horizontal line*:—Select a piece of level ground, set vertical circle to zero and level up instrument over a definite point ascertained by plummet. Measure off accurately a given distance of (say) 50 to 100 yards in opposite directions. Drive a peg in each of these points. Set up staff on each, drive pegs in until staff reads same on both. (Note—Man holding staff should be instructed to incline staff forwards and backwards during operation of reading to prevent any error due to staff not being held vertically.) If these operations are done correctly the top surfaces of the two staff pegs are level. Remove theodolite to a new position of (say) 20 yards from one of the staff pegs. Take readings from both pegs in the new position. Any error can be adjusted by means of the two vertical screws holding the diaphragm in position.

The above adjustments should be followed through in the order given.

CHAPTER XII

TRAVERSING

Traversing is a very important and necessary branch of surveying. There are two methods :—

1. By reading the angles included by each two adjacent survey lines, called *Gale's* or the *Included Angle* method.
2. By taking the bearing of each line, i.e. the angle contained by the survey line and the meridian, called the *Back Angle* method.

A survey by traverse may be what is termed *open* or *closed*. In the former case the survey lines are not continued until they come back to the starting point, and in the latter they return to the point of origin. Obviously the closed traverse is better because of the check afforded by closing correctly on the first station. But a route may be traversed from one fixed point on a plan to another and a check thus obtained by exactly hitting off the fixed station. When it is not necessary to return to the beginning, for the purposes of the survey, it will nevertheless be advisable to do so for the purpose of the check such a course will provide. The instruments which are used for the work are the prismatic compass and the theodolite. It is preferable to use the latter. The readings are booked as so many degrees to the East of North.

Field Work.—The object to be achieved is to manipulate the theodolite in such a manner that the meridians at each station are kept parallel to one another. The two methods mentioned above effect this object.

1. **Gale's *or* the Included Angle Method.**—Pickets or poles are placed in the ground at the essential points so as to encompass the area to be surveyed (see Chapter II, Fig. 39), or if surveying a road as shown in Chapter X, Fig. 158. The theodolite is set up over the first station and levelled up. The telescope is turned in the direction of the north and when pointing thus, the plates should be clamped at zero. Now direct the telescope on to the second station and take the reading, thus obtaining the bearing of the first line. This is the only bearing which is taken in the

traverse, the remaining bearings being calculated from this one. Before moving the theodolite take also the angle included between the two adjacent survey lines at this station. Now transfer the instrument to the second station and observe the included angle by sighting first on to the back station and swinging round on to the fore station. Do the same thing at each successive station until all the included angles have been observed.

To calculate the bearings.—Add together the bearing of the preceding line and the angle contained between the lines. If the sum so obtained exceeds 180°, deduct 180° from it; but if the sum

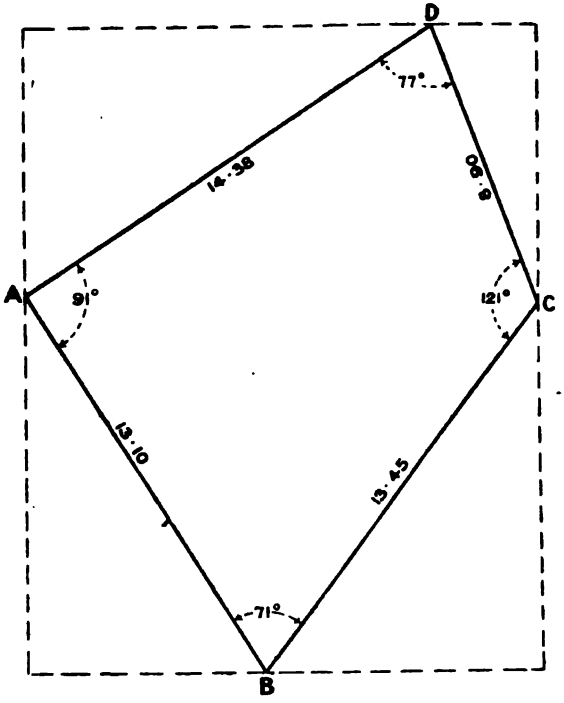


FIG. 164.

be less than 180° then add 180° to it. If, however, after deducting 180° we get a greater sum than 360° then we must deduct a further 360°.

Example.—The external angles or the internal angles may be read, but it is better to read from left to right always, when possible, with the theodolite.

The sum of the interior angles *plus* four right angles is equal to twice as many right angles as the figure has sides. The sum

of the exterior angles *minus* four right angles is equal to twice as many right angles as the figure has sides. We thus have a check upon the angles of the traverse.

Set up and level the theodolite at the station A (Fig. 164). Chain the first line AB, take its bearing and also the included angle between it and DA. Remove the instrument to B, chain BC, and take the included angle ABC. Proceed thus with the remaining lines.

The bearing of AB has been taken and is 147°. The bearing of BC is found by the rule given above. ABC = 71°; AB bears 147°; added together they equal 218°; *subtract* 180° and the bearing of BC is found to be 38°. The bearing of CD is found similarly. BC bears 38°; BCD = 121°; added together they equal 159°, *add* 180° and the bearing of CD is found to be

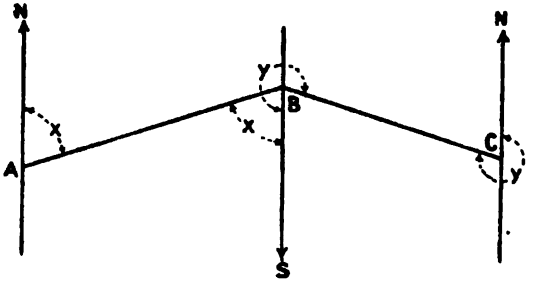


Fig. 165.

339°. The bearing of DA = (339° + 77°) − 180° = 416° − 180° = 236°.

If the exterior angles had been read—that is, if the chaining had been the reverse way—then the bearings would differ by 180°.

Example.—The bearing AD would be 56°. The exterior angle ADC = 283°: add this to 56° and we get 339°; subtract 180° = 159°, the bearing of DC.

2. **The Back Angle Method.**—In this method the bearing of each line is taken. Having fixed the stations, as explained before, set up the theodolite over the first station. Clamp the plates at zero and turn the telescope to north. Now take the bearing of the first line. Next move the instrument to the second station and set it up. With the bearing of the first line still on the vernier, direct the telescope back on to the first station and accurately bisect it with the cross-hairs. Now turn the instrument to zero and the telescope should be pointing parallel to its original direction but the opposite way—namely, to the south, unless some error has been made. (See Fig. 165.)

The bearing of AB is the angle X. When the theodolite is set up at B the vernier is reading the angle X and is directed on to the first station A. On turning the vernier to zero the instrument will be found to be facing south. Now turn the telescope in the direction of C and we shall get the angle Y, which is the bearing of BC measured from the south. Set up the instrument at C with this reading clamped and direct the telescope on to the back station B. On setting the vernier to zero it should be pointing to the north, and the bearing of CD can be read. Proceed in a similar way for all the stations. The bearings are thus observed alternately from the north and the south, and parallelism of

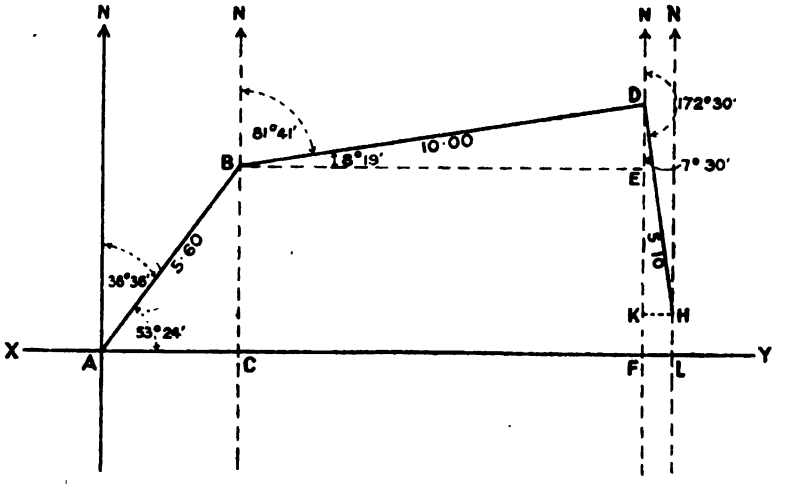


Fig. 166.

meridians is kept automatically. The lines are measured and offsets taken as required in the ordinary way.

Plotting the Traverse.—If the angles are plotted with a protractor there is every probability of an error creeping in, and if such error occur at the beginning in the direction of a line there will be great discrepancy in the work at the end of the line. To avoid this difficulty of measuring the angles with a protractor, a system of plotting the work *by co-ordinates* is adopted. It is as follows: In Fig. 166, Line 1 (AB) bears 36° 36′ East of North and is 5·60 chains long. Line 2 (BD) is 10 chains long and bears 81° 41′ East of North. Line 3 (DH) is 5·10 chains long and bears 172° 30′ East of North.

Having pinned a piece of drawing paper on the board take a T square and draw a line which we will call XY. The station A

may be taken at any point in XY or at any certain distance above it. To locate station B it is necessary to calculate the lengths AC and BC according to the rules for right-angled triangles given in the chapter on Trigonometry. To plot the work only a T square, set square, and scale are required.

Find AC and BC by the rule for solving right-angled triangles. Find the lengths BE and DE, also the lengths DK and KH similarly. To plot the work the length DE must be added to BC to obtain the

Station	Observed Bearings	Reduced Bearings	Distances	Equations	Workings	N +	S −	E +	W −	Dep.	Lat.
A										0	0
	36° 36′	53° 24′	5·60	AC = 5·60 cos 53° 24′	0·7481880 1·7754101						
					0·5235981 = 3·34			3·34			
				BC = 5·60 sin 53° 24	0·7481880 1·9046168						
					0·6528048 = 4·50	4·50					
B										3·34	4·50
	81° 41′	8° 19′	10·00	BE = 10 cos 8° 19′	1·0 1·9954087						
					0·9954087 = 9·90			9·90			
				DE = 10 sin 8° 19′	1·0 1·1603005						
					0·1603005 = 1·45	1·45					
D										13·24	5·95
	172° 30′	7° 30′	5·10	DK = 5·10 cos 7° 30′	0·7075702 1·9963686						
					0·7038388 = 5·06		5·06				
				KH = 5·10 sin 7° 30′	0·7075702 1·1156977						
					1·8232679 = 0·67			0·67			
H										13·91	0·89

Fig 167.

length DF, and BE must be added to AC to obtain AF. DK must be subtracted from DF and KH added to AF to obtain the position of H. All vertical lines are worked out and plotted from the base XY and all lateral distances from the point A: the departures being marked off to scale along the line XY and the latitudes plotted from these points by means of the set square and scale. The lengths of the vertical lines denote the difference of latitude between the points. Consequently if we assume the line XY to

be at a latitude of 0, the lengths BC and DF will denote the *latitudes* of the points B and D.

These lengths are called the *latitudes* of the stations in a traverse survey. If we assume the longitude of A to be 0, then the lengths of AC and AF will denote the *longitude* of the points B and D. These longitudes are usually called *departures*, being the amount of departure east or west of the original meridian.

The reducing of the traverse is done as shown in Fig. 167. In plotting the traverse it will be seen that only the *Latitudes and Departures* need be referred to, in the same way as only the Distance and Height above Base columns need be referred to when plotting a level section.

The latitudes and departures of the first station may be assumed either as 0 in each case, or at some figures which are sufficiently large so as to prevent getting below zero when all deductions have been made—as is the case in levelling when determining the value of the H.A.B. of the Bench Mark.

The results of the workings are placed in the N., S., E., W. columns according to whether they go N., S., E., W. from the point at which the bearing was taken. Northings and southings are respectively added to or deducted from the previous latitudes, and eastings and westings are respectively added to or deducted from the previous departures.

It will be observed that, by this method of plotting, each point of the traverse is independent of the other, and a mistake made in one point is not carried to others. It should, therefore, always be adopted in preference to protracting the angles.

Closing Error.—It will be found that in a closed traverse the last line seldom closes exactly on the original station. When a traverse closes the following three conditions must be fulfilled :—

1. All the interior deduced or observed angles together with four right angles must be equal to twice as many right angles as the figure has sides.
2. The northings must equal the southings.
3. The eastings must equal the westings.

In ordinary traverse surveys the closing error should not exceed one link in 3 chains, or (say) $\frac{1}{500}$th part of the perimeter. The error may be ascertained by dividing the square root of the sum of the errors of latitudes and departures by the whole perimeter : this will indicate whether one is within the limit of error allowed.

Convergency of Meridians.—In reality the meridians are not parallel, as they converge to the poles ; but for ordinary purposes this is a negligible quantity.

Adjustment of Closing Error.—Having decided that we are within our limit, the C.E. should be adjusted and the traverse made to close before the offsets are plotted. This may be done graphically in the following manner :—

In Fig. 168 let ABCDEX be a traverse survey as plotted, showing the closing error to be AX. Draw a line aX (Fig. 169) equal in length to the periphery of the traverse: divide this line into distances ab, bc, cd, de, eX equal respectively to the sides AB, BC, CD, DE, EX of the traverse. Draw XA perpendicular to aX, making

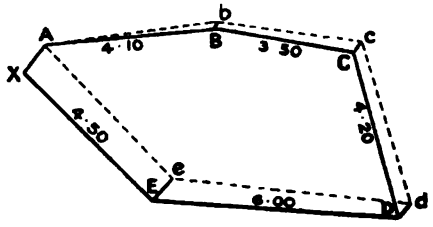


FIG. 168.

XA equal to the total closing error measured from the plot in Fig. 168. Join aA and draw the perpendiculars bB, cC, dD, eE. This will give the amount of correction to be made at each of the stations of the traverse. To make the correction, draw through

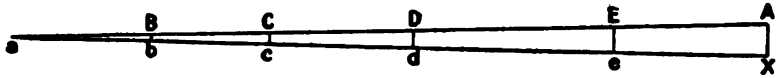


FIG. 169.

each station a line parallel to AX (Fig. 168), and on each of these lines measure off the distances Bb, Cc, Dd, Ee which are found from Fig. 169. The points A, b, c, d, e should now be joined, and the traverse will be so adjusted as to close on its origin point.

Field Book.—The usual form of book may be used. The bearing of each line is written against the number of the line.

CHAPTER XIII

TACHEOMETRY

Tacheometry.—The word, which is derived from the Greek, signifies to measure quickly. A tacheometer is an instrument almost exactly like a transit theodolite, but with a larger telescope.

An ordinary theodolite fitted with a diaphragm containing stadia as shown in Fig. 170 (termed a subtense telescope) may be used as a tacheometer. (See also Fig. 95, Chapter VI.)

Diaphragm.—The wires *a* and *b* are often engraved on glass at the proper distance by the maker, and are generally placed apart at a scale of 100 or 200. They may also be adjustable as to their distance from the central wire by means of screws. When this is the case, in order to find the scale we measure 100 feet on the ground (+ K, mentioned later), adjust the instrument, and note the readings of the extreme wires. If the difference of readings is 1 foot, the scale is $\frac{1}{100}$; if the difference is 0·50, the scale is $\frac{1}{200}$.

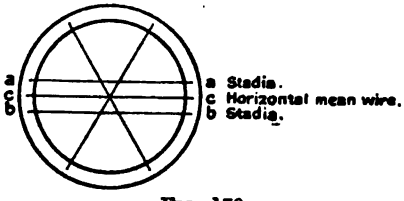


FIG. 170.

The object of the stadia points is to measure distances without chaining them.

If the staff be graduated into feet and hundredths of a foot, then the distance from the object glass to the staff is the length subtended by the wires on the staff multiplied by 100 or 200, as the case may be, *plus* the solar focal length of the object glass. (Solar focal length is the distance of the image of the object from the centre of the lens.)

But the distance of the staff from the centre of the instrument is required, so that a further addition of the distance from the object-glass to the centre of the instrument must be added. This constant is generally given by the instrument maker.

Then the correct distance is equal to the difference of the readings of the extreme wires multiplied by 100 (or 200) *plus* the constant (K).

Besides the distances A*a*, A*b*, A*c*, A*d*, A*e*, a tacheometer also

enables as to obtain (Fig. 171) the angles made at A by the points *a*, *b*, *c*, *d*, *e*, and the differences of level between A and *a*, *b*, *c*, *d*, *e*. If the R.L. of A be known, the R.L.'s of *a*, *b*, *c*, *d*, *e* can be calculated.

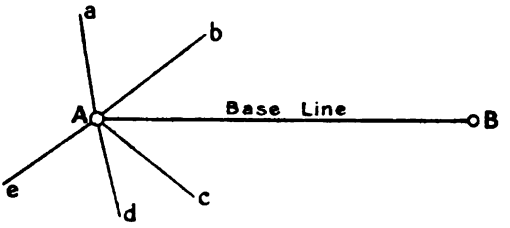


FIG. 171.

Mode of Ascertaining a Distance.—Hold a level staff over a station, and having adjusted the tacheometer, direct the telescope to the staff and take two readings with the wires *a* and *b* (Fig. 170). The greater the distance of the staff from the instrument the greater will be the difference between the two readings.

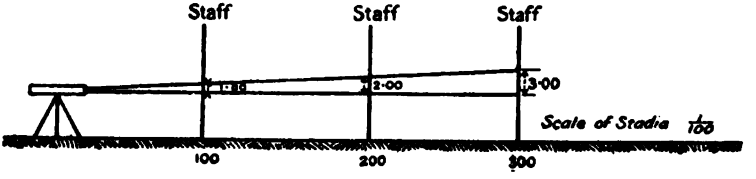


FIG. 172.

Example (Fig. 172).

Suppose the higher reading = 7·42
" " lower " = 3·36

Difference = 4·06

Then, if the wires are adjusted so that the difference is 100 times this, *the length will be* 406 *feet* (+ K).

It must be noted, however, that this will be the true horizontal distance only if the telescope points in a level line and the staff is held upright. The ground may be considered to be level when the inclinations do not exceed 3° to 4°.

If the line of sight has to be elevated or depressed, we shall obtain the distance measured on the slope along the line of sight, *provided that the staff was at right angles to the line of sight.*

In practice the staff is held *upright* and the direction of the telescope is parallel to the slope (Fig. 173). The true length of the horizontal distance is then found as follows :—

If the telescope be inclined so that the line of sight falls above or below the horizontal, it is obvious that the line drawn through the centre of the instrument to the staff is longer than it would be were the telescope horizontal, and consequently the number of divisions intercepted on the staff is greater, in proportion to the angle of inclination, than would be the case if the telescope were horizontal. The number of divisions must, therefore, be reduced by multiplying them by the cosine of the angle of elevation. The distance thus obtained is that *along the angle of inclination* and it must be multiplied into the cosine of that angle.

The usual practice is to take the distance on the slope as calculated directly from the interceptions without reduction, and to multiply the result into the *cosine squared*. This gives the same figures.

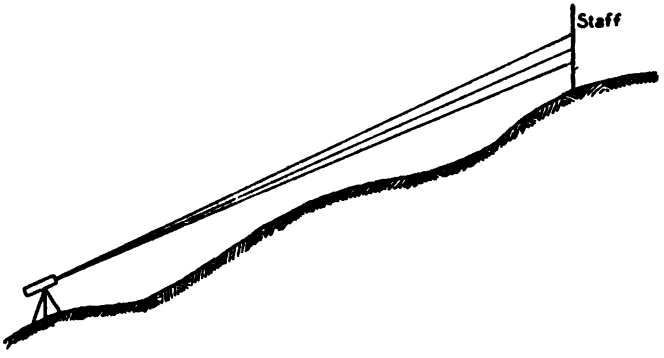


FIG. 173.

The following formulæ may be used conveniently :—

$$H = D \cos^2 E$$
$$V = H \tan E$$

where H = the horizontal distance;
D = the difference of readings multiplied by 100 (or 200);
E = the angle of elevation or depression;
V = the vertical height.

Example.

The readings on the staff = 7·42
3·36
Their difference = 4·06
Scale of stadia (say) 100 = 100
∴ D = 406 say, corrected

Now, H = D cos² E—i.e. 406 × cos E × cos E.

Suppose the angle of elevation to be 5° 15′.

Then

$$\log 406 = 2{\cdot}6085260$$
$$\log \cos 5° 15' = \bar{1}{\cdot}9981743$$
$$\log \cos 5° 15' = \bar{1}{\cdot}9981743$$
$$\therefore \log H = 2{\cdot}6048746$$
$$\therefore H = 402{\cdot}60 \text{ feet}$$

and $V = H \tan E$

$$\log H = 2{\cdot}6048746$$
$$\log \tan 5° 15' = \bar{2}{\cdot}9632545$$
$$\therefore \log V = 1{\cdot}5681291$$
$$\therefore V = 36{\cdot}993 \text{ feet.}$$

In order to avoid the addition of the constant K at each reading, a third lens, called an ' anallatic lens,' was introduced by J. Porro. It is, however, not of any great advantage to avoid adding the constant, and the third lens causes considerable loss of light. The telescopes of tacheometers fitted with this lens are necessarily of a large size, and their eye-pieces generally possess a greater magnifying power than those of theodolites.

To Survey with the Tacheometer.—Set up the instrument in some position which commands a good view of all, or as many as possible, of the stations of the survey.

Take an observation to each station and book—

(*a*) The bearing of each pole.

(*b*) The two readings to the staff held on the point.

(*c*) The angle of elevation or depression, entering angles of elevation with a *plus* sign and angles of depression with a *minus* sign.

All the stations can be plotted from this information, and there is no necessity for triangulation.

As it is important always to hold the staff upright, it is often provided with a plumb-bob. It is advisible to direct the lower cross-hair to a round number, say one foot: this facilitates calculations. The height of the instrument should also be ascertained.

CHAPTER XIV

LINING OUT CURVES

Curves may be designated either by the length of the radius or by what is termed the 'degree of curvature.' By the degree of curvature is meant the angle which is subtended at the centre of the curve by a chord of 100 feet in length. A tangent to a circle

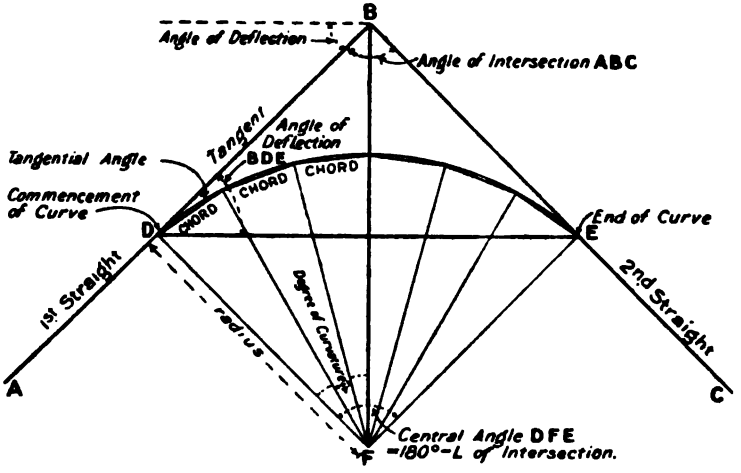


FIG. 174.

is perpendicular to the radius drawn to the point of contact. Two tangents drawn to a circle from any point are equal, i.e. BD = BE (Fig. 174). If a chord be drawn between the two points of contact of the tangents, the angles formed by the tangents with the chord are equal, i.e. BDE = BED.

The following information is necessary before we can lay out a curve :—

1. Two straight lines to be joined.
2. The length of the radius or the degree of curvature.

We must also calculate the point of commencement of the curve and its length.

The instrument to use for the field work is the theodolite. In Fig. 174 the two straights which are to be joined by a curve are AD and CE.

To determine the commencement of the curve.—Before commencing operations in the field, the curve may be laid down on the 25-inch Ordnance Map. This will make it easier to line out the straights so as to find the intersection point. This should be done with the theodolite. Having found the point of intersection B (Fig. 174), set up the theodolite over it and observe the angle ABC. As F is the centre of the circle FB bisects the angle ABC. We can therefore ascertain the angle ABF. Suppose the radius has been decided upon; we have then sufficient data (viz. FD, FBD, and BDF which is a right angle) to ascertain the length of BD.

$$BD = FD \times \cot FBD$$

Measure the distance BD back from the intersection point B and we have the commencing point of the curve.

If, however, we have decided upon the degree of curvature for the curve, we must nevertheless find the radius before we can find the commencing point. This may readily be done by the following formula :—

$$\text{Radius} = 1719 \times \frac{a}{x}$$

where a = the chord of 100 feet and x = half the degree of curvature expressed in minutes.

Example.—Find the radius of a 3° curve.

$$r = 1719 \times \frac{100}{90}$$

$$= 1910 \text{ feet}$$

To ascertain the tangential angle.—Having found the point of commencement, it is necessary to determine the tangential angle before we can start pegging out the curve. The tangential angle is the angle of deviation which the first chord of the curve makes with the tangent to the curve at its point of commencement.

If we set out the curve with a radius of so many chains, we use a chord of 1 *chain of* 66 *feet*, and the tangential angle is found by dividing the constant 1719 (really 1718·873) by the radius of the curve in chains, the result being the tangential angle in minutes for a chord of 1 chain.

On the other hand, if we set out the curve with the degree of curvature decided upon, the tangential angle is always half the degree of curvature; thus the tangential angle of a 4° curve is 2°, and we use a chord of *one chain of* 100 *feet*. It will *thus* be seen that it is simpler to adopt the latter method. Tables of tangential angles are published to save the trouble of calculation.

To find the length of the curve.—As each chord of 100 feet subtends at the centre an angle equal to the degree of curvature, the length of the curve equals the whole central angle divided by the degree of curvature multiplied by 100 feet. This really gives the length of the chords in the curve and not the curve, but the difference between the chord and its arc is so small that the length of the curve so obtained may be taken as correct.

The length of the curve in chains may also be found by dividing half the angle of intersection by the tangential angle for one chain: or the angle of deflection divided by the tangential angle equals the number of chords in the curve.

To set out the curve.—*With the theodolite.*—Whether we set out the curve with the chord of 1 chain of 66 feet or 100 feet, the method of doing so is the same in the field.

Set up the theodolite over the tangent point of the commencement of the curve with the vernier set to zero. Sight on to the pole at the beginning of the first straight and, reversing the telescope, note whether the cross-wires bisect the point of intersection. Set the vernier to the angle of deflection of the whole curve and note whether the cross-wires bisect the second tangent point.

Now, having satisfied the above tests, set the vernier to zero and point the telescope in the direction of the tangent to the curve. Next, set the vernier to the first tangential angle, say 2°, and chain a distance of 1 chain; but instead of going in the direction of the straight line, go in the direction in which the telescope is pointing and drive in a peg at the end of the chain's length, with the cross-wires accurately bisecting the peg when driven in. In this way the first point on the curve is obtained. To obtain point 2, multiply the tangential angle by 2, and turn the telescope until the vernier reads this new tangential angle, 4°. Chain a further distance of 1 chain from the first point so that the extremity may be in the direction of the telescope. The remaining points may be fixed in a similar manner by multiplying the first tangential angle by the number of the point on the curve, and chaining the length of 1 chain from the last point in the direction of the telescope.

As the centre line of a road is generally pegged out in 1-chain lengths it seldom happens that the commencement of the curve is at one of these pegs. If the last peg in the straight is (say) 2,000 feet and the curve commences at 2,020 feet, then the first chord of the curve will only be 80 feet in length, and $\frac{4}{5}$ of the tangential angle must be set off on the vernier and a peg driven in at 80 feet instead of 100 feet. Thus, if the tangential angle is 2° for a chord of 100 feet, then for a chord of 80 feet it is 1° 36′. The same thing applies when the last chord is not a full 100 feet.

Curves may be set out *left handed*—that is, bending in the opposite way to which the theodolite is graduated. The method is precisely the same as for right-handed curves, but the degrees must be

counted off in the left-handed direction and the minutes read off the vernier in its reversed position.

Impeded point in curve.—It is generally the case that it is not possible to see all the points on the curve from the first position of the instrument. It is then necessary to remove the theodolite to the last peg observable, and proceed when there in a manner similar to that adopted in the back angle method of traversing. Set up the instrument over the new station (i.e. the last peg observed from the first station) with the reading of the tangential angle for that station still upon the vernier. Sight back on to the first station, accurately bisecting the peg. Now set the vernier to zero and the telescope will be pointing parallel to the first tangent. The direction of the new tangent is obtained by turning the telescope through 180° plus *twice the tangential angle of the new station from the first station.* Set out the remainder of the pegs on the curve as before, adding on the necessary tangential angles.

Without the theodolite.—A rougher method of lining out curves with the chain by *chord and offset* may be adopted, but the results are not so satisfactory.

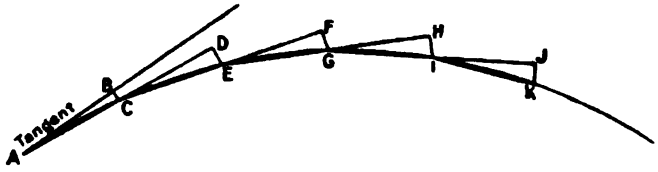


FIG. 175.

Having determined the commencement of the curve, &c., as already described, measure off along the tangent AB a distance equal to 100 feet. (Fig. 175.)

At B set off a distance BC, at right angles to AB, and equal to $\frac{\text{chord}^2}{2\,R}$. C is then the first point on the curve.

Now, from C measure another 100 feet CD in line with C and A. and on CD as base construct the triangle CDE having CE equal to 100 feet and DE equal to $\frac{\text{chord}^2}{R}$ (i.e. double the last). Thus the second point E is obtained. The remaining points G, I, K, &c. are found similarly to the second, the offsets being the same—namely twice the first one.

To correct the curve.—As in the case of a traverse the curve will seldom close exactly on the second tangent point. When setting out with the theodolite the permissible error may be taken as 1 in 1000; without the theodolite as 1 in 300.

The error may be corrected graphically in the same manner as shown for the correction of a traverse (Chapter XII).

PART II

BUILDING CONSTRUCTION

CHAPTER XV

PREPARATIONS FOR BUILDING: EXCAVATION: FOUNDATIONS: CONCRETE: CEMENT

At the outset of all building work, it is naturally of extreme importance that the preliminary operations should be carried out with care. It is scarcely necessary to state that the site should be properly cleared of all vegetable growth, and in most cases levelled. As all drawings should clearly show dimensions such as affect the setting out of any building, it is an easy matter to find therefrom the exact positions for the various trenches which have to be dug for the foundations. These positions should be carefully marked on the site by means of pegs driven into the ground. The depths of these excavations are governed by two things :—

1. The thickness of the wall, and the weight of the superstructure.
2. The nature of the subsoil.

In the first case, where ordinary farm and estate buildings are to be considered, the thickness of the wall will only in extremely rare cases exceed a brick and a half—or what is generally known as a 14-inch wall—and even this dimension is greater than will be generally adequate. But, whatever the thickness of the wall may be, it is usual for about 12 inches of the wall proper to be built below ground level. Below that level the footings project in courses in order to spread the weight of the wall upon the concrete foundation. These brick footings project 2¼ inches on each side of the wall as shown in Fig. 176, and continue so to do until their lowest course is twice as thick as the wall above. In the case of 18-inch walls and upwards the lowest course of footings should be doubled in depth. Another point which should not be overlooked is that headers should be employed as far as possible in order to insure the weight of the wall being spread to the outside edges of the lowest course of footings. In cases where great weight has to be provided for, it is a common practice to use bricks of a harder and more durable nature, such as Staffordshire blue bricks, but such a necessity is unlikely to occur often in estate work.

All excavation should be done at the same time, and when the trenches for foundations have been made, similar provision

must be made for all drain-pipes, whether sewage or rain-water. And as in dwelling-houses the ground must be sealed over the whole site with concrete—and in a similar way all stock-houses should be provided with some form of impervious flooring—it is necessary to excavate to a certain depth and cast away all the superfluous material from the site. The depth of this surface excavation will, of course, be decided by the particular type of building and the nature of the floor. But in every case there must be what is called a 'core' or bed of hard, dry, broken material as a firm bottom to the concrete or other floor. This 'core' may consist of broken bricks, local stone, or any hard, dry, and clean material. As already stated, the depth of the concrete foundation will depend both upon the weight it has to carry and upon the nature of the subsoil, which may be either extremely firm in itself, and capable of solidification by ramming, or of a shifting, unstable nature. As it is impossible to deal with the multitude of possibilities in this matter it is perhaps better to assume reasonable and normal conditions and to take the depth of the concrete foundations as varying between 9 and 12 inches. It is now necessary to insure the level of the upper surface of the concrete being maintained throughout. This is easily done by driving into the bottom of the trench, some few feet apart lengthways, stakes whose heads, tested by a spirit level, are all in the same plane. The concrete can then be kept from rising above the correct height by placing a plank on edge on the pegs and swinging it backwards and forwards.

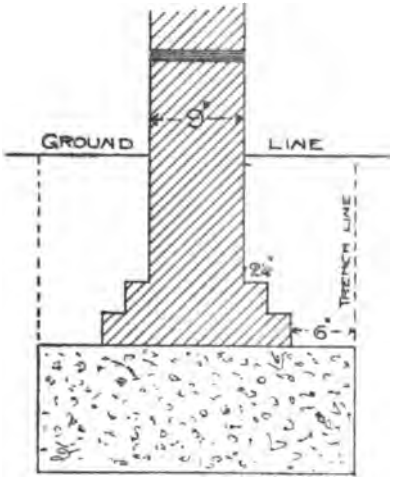


FIG. 176.

By the time the concrete has properly set the trench will be filled, to a depth of about 12 inches, with what can be called an artificial stone, in one homogeneous body, entirely without joints.

In the case of a concrete floor or sealing for the ground underneath a timber floor the material is spread upon the previously laid 'core' to a depth of from 4 to 6 inches.

Where the superimposed weight is not great and expense is decidedly an object, both time and money may be saved in the making of concrete foundations by the judicious use of 'plums'—a name given to large stones placed in the trench and then surrounded and covered in by the concrete. These should never occur more

frequently than one to every six feet, as the concrete is liable to weakness and a lack of homogeneity on their account.

Concrete is, as already stated, an artificial stone and can be made in two qualities :—

1. Cement concrete, the more durable and expensive.
2. Lime concrete.

In both cases the preparation is exactly the same, and consists of the mixture of :—

1. Matrix—lime or cement ; and
2. Aggregate—broken bricks, granite chippings, coke-breeze, clinker, or any clean similar material.

There should also be a certain proportion of sand in order to improve the binding tendency of the entire mass. This sand should be as sharp, fine, clean, and irregular as can be obtained ; and for these reasons sea sand is not nearly as satisfactory as river or pit sand.

In the mixture of concrete the idea is that the sand fills the interstices between the portion of aggregate and the lime or cement fills those between the particles of sand, and so all spaces and gaps are prevented. This operation is one of extreme importance and should never be done without proper supervision and great thoroughness.

The operation should take place for preference upon an old and smooth concrete floor, and failing that a platform of about 10 feet square composed of few and smooth and evenly jointed boards, raised a few inches above the ground level in order to prevent vegetable or earthy matter from being incorporated in the mass of concrete. For the sake of accuracy the matrix and aggregate should be measured by the use of gauge boxes, which are made without bottoms and according to the proportions decided upon. The larger box is first placed upon the mixing board or floor and filled with the aggregate and upon the top of this is placed the smaller box which is filled with the matrix. Both boxes are lifted off, leaving a heap of material, which should then be thoroughly turned over twice in a dry condition, and then twice in a wet condition, the water being added from a watering can fitted with a rose. When the particles of the mixture are thoroughly incorporated with each other and none remain in a dry condition the concrete is ready for use and can be shovelled into wheel-barrows, and thence into trenches or wherever the work may be intended. It must be remembered that since cement sets quickly when mixed with water, no more than is necessary and sufficient for the day's consumption should be mixed at one time, as it cannot be used after leaving it mixed up from one day to the next.

Lime used in building work should be freshly burnt and can be described in the following ways :—

1. Pure lime which sets on the outside, but drys without setting inside.
2. Poor lime—a mixture with impurities which do not benefit its setting qualities.
3. Grey stone lime—slightly hydraulic.
4. Blue lias lime—eminently hydraulic.

The term 'hydraulic' denotes the capacity for setting in the absence of air, and as such limes as more difficult to slake than others they should be ground before use.

Great care should always be bestowed upon the choice of cement, and no hesitation should be shown in refusing any but that which is clearly marked upon the bags in which it is sold as 'Best English Portland Cement.' A great quantity of inferior material comes from abroad, and is mostly of a natural type, by which is meant that it is taken out of the ground and packed for shipment in its raw state, irrespective of the fact that it contains a vast quantity of impurities which tend to neutralise its efficacy. Portland Cement is a British invention—not yet a hundred years old, and is made mostly in Kent under the auspices of the Associated Portland Cement Manufacturers (1909) Limited. The choice and use therefore of none but that clearly marked as 'Best English Portland Cement' will insure the correct proportioning and a satisfactory result. In the main, Portland Cement is made from two raw materials—chalk and clay—which are accurately proportioned and mixed together and then burnt until a hard clinker is produced. This is then finely ground and forms the powder which is called Portland Cement.

Concrete is usually measured by the yard cube, and for various uses should be proportioned as follows :—

	Matrix	Aggregate	
		Sand.	Broken material
Reinforced Concrete . .	1	2	4
Foundations, walls, arches ordinary floors and stairs . .	1	2½	5
Heavy walls, piers, etc. . .	1	3	6
Sealing to ground . . .	1	4	8

The materials used for one cubic yard of cement concrete proportioned as above are :—

Proportions	Portland Cement lb.	Sand cubic yards	Broken Material cubic yards
1 : 2 : 4	590	0·44	0·88
1 : 2½ : 5	485	0·45	0·91
1 : 3 : 6	414	0·46	0·93
1 : 4 : 8	320	0·48	0·96

As regards the water required, this should be as pure as possible and free from acids or strong alkalis. The bad quality of the water

frequently affects the strength of the concrete. The average quantity of water required for making concrete is from 21 to 24 gallons per cubic yard of dry materials. The aggregate should be broken sufficiently small so that no piece is too large to pass through a 2-inch ring.

Prices

	Per	s.	d.
Excavation in common soils (earth or gravel) in trenches for foundations or drains, and part returned, filled in and rammed, not exceeding 6 feet in depth	yard cube	1	3
Excavation as above and carting away whole	,,	4	3
Hard core filled in and rammed	,,	2	6
Levelling and ramming surface of excavation	yard super.	0	3
Excavation to surface, average 6 in. deep and levelling and ramming	,,	0	5
Excavation to surface, average 12 in. deep and levelling and ramming	,,	0	9
Hard core 4 in. thick, filled in and rammed level	,,	0	4
,, 6 in. ,, ,, ,, ,,	,,	0	6
,, 9 in. ,, ,, ,, ,,	,,	0	8
,, 12 in. ,, ,, ,, ,,	,,	0	10
Cement concrete paving and floors (6 to 1) 3 in. thick	,,	1	4½
,, ,, ,, ,, 4 in. ,,	,,	1	10
,, ,, ,, ,, 6 in. ,,	,,	2	9
,, ,, ,, ,, 9 in. ,,	,,	3	9
Cement concrete (yard cube)	12/0 to	14	0
Lime concrete ,,	9/0 to	11	0
Keene's cement	bushel	3	9
Martin's cement	,,	5	6
Parian cement	,,	3	9
Roman cement	,,	1	9

CHAPTER XVI

BRICKS : STONES : BRICKLAYER'S AND MASON'S WORK : ROOF COVERINGS

Bricks and Brickwork.—It is not necessary to give here an account of the preparation of the brick earth and the various processes it passes through in the production of bricks. It must, however, be clearly understood that bricks are either burnt in a clamp or in a kiln.

A clamp is a stack of raw bricks built up with flues to allow fuel to be burnt within the four-sided pyramid. These bricks are called 'stocks,' and are generally used for the internal parts of walls, also in facing work where it is proposed to rough cast. For these purposes they are well adapted as, in addition to their strength, their rough surfaces provide a very useful key for plaster, both internally and externally. Picked stocks—i.e. chosen for equality of colour are sometimes used for facings. A kiln is a specially prepared chamber of brickwork provided with properly formed flues, which hold from 20,000 to 50,000 bricks. The method by which a brick has been made can be determined as follows :—

Hand Moulded.—Frog (i.e. depression rectangular in shape) on one side. Somewhat lacking in form and finish, and porous.

Machine Made.—Without frogs. Good in form and less porous. Marks indicating wire-cutting noticeable.

Pressed Bricks.—Smooth faces on some or all sides, clean and sharp angles. Frog on one or both sides. Trade mark visible within the frog. Even less porous than the above.

Clamp Burnt.—Colour not uniform. Coke breeze visible either on surface or when the brick is broken across.

Kiln Burnt.—Stripes on the sides of the bricks of light and dark colour.

Varieties of Bricks.—*Gault Bricks.*—Composed of Gault clay.

White Suffolks and Beart's Patent Bricks.—Varieties of Gault bricks.

Suffolk Bricks.—Made expressly for facings and are expensive. Of an inhospitable and cold colour.

Red Bricks.—Very hard and strong.

Dutch Clinkers.—Small, well burnt, and hard. Used for paving, and usually 6″ × 3″ × 1″.

Adamantine Clinkers.—As above but harder, denser, and heavier. Pale pink in colour, with smooth surfaces.

Enamelled Bricks.—White or yellow surface like china and are used in lavatories, dairies, &c.

Salted Bricks.—Thin glazed surface produced by throwing salt into the fire during burning.

Fire Bricks.—Will stand excessive heat. Yellow in colour and close in texture. Used for ovens, furnaces, and the like.

Attributes and Test of Good Bricks.—Shape and size regular and uniform; compact and flawless. On saturation should not absorb more than about 15 per cent. of their own weight of water, and should part with it freely at moderate temperature. Uniformly

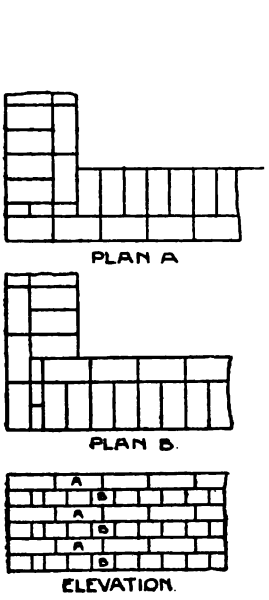


Fig. 177.

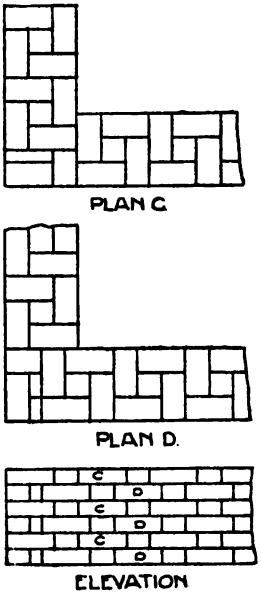


Fig. 178.

burnt, and should give a metallic ring when two are knocked together. Should require several blows before breaking, and should stand carting and handling well.

The size of a brick (9″ × 4½″ × 3″) is reckoned as including the mortar joint which should exactly make up for the discrepancy in size between the brick in the raw and after burning, as a certain amount of shrinkage naturally takes place. Good brickwork should show four courses to the foot vertically.

The two most important bonds in brickwork—i.e. the method

of arranging the bricks in juxtaposition to each other in the successive courses of a wall, are :—

1. English—stronger of the two. (See Fig. 177.)
2. Flemish—more pleasing in appearance. (See Fig. 178.)

The English Bond, as will be seen in the diagram, consists of alternate courses of 'headers' and 'stretchers'—i.e. bricks laid across the wall, showing their ends on the face of the wall in the alternate courses, and bricks laid along the wall end to end in the intermediate courses.

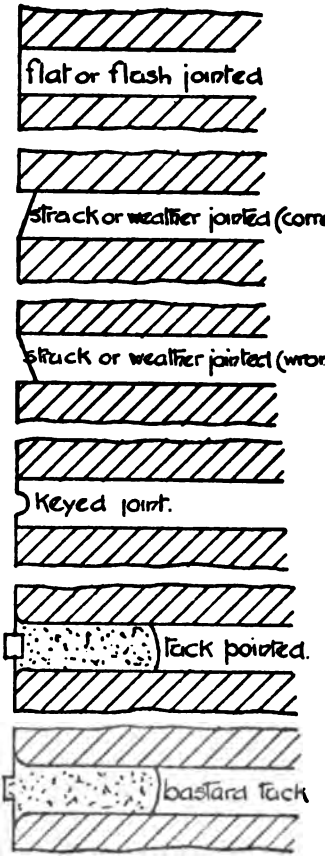


FIG. 179

The Flemish Bond consists of alternate headers and stretchers in each course.

As will be seen in the diagram, it is necessary, in order to prevent the vertical joints of one course coinciding with those of the courses immediately above and below, to introduce a 'closer' which measures 2¼ inches across and must occur as the penultimate member of every other course and at each end.

The jointing material which is, of course, necessary to bind the bricks or any other kind of walling together may be either :

1. Lime mortar composed of 2 to 3 parts of sand and 1 part of lime ; or
2. Cement mortar composed of 1 to 4 parts of sand and 1 part of cement.

It must be remembered that whereas lime mortar benefits from being made and left for a few days, and then made up again, cement mortar must always be used immediately it is made, as when the cement has once set it is useless to break it down again. Lime mortar should be composed of pure lime which is non-hydraulic, as the difficulty in slaking hydraulic limes renders the action likely to take place after setting, which results in small patches being blown out.

Two cubic feet of sand, 1 of lime, and 7½ gallons of water will produce about 2½ cubic feet of mortar.

Gauged lime mortar, which is used on account of its capacity for setting quickly, is composed of 1 part of lime, 1 part of Portland cement, and from 4 to 6 parts of sand.

Pointing, which is the process of finishing the face jointing in brickwork, and gives a neat appearance, is shown in detail in Fig. 179.

Bricks should be wetted immediately before use for the purpose of removing any dust thereon, also to prevent the dry brick absorbing moisture from the jointing material.

The standard of measurement of brickwork is the Rod which equals 272 superficial feet at a brick and a half thick. In estimating the number of rods in a wall whose thickness is either 4½ inches, 9 inches, 18 inches, and so on, it is a simple matter to reduce to terms of the standard thickness as it will be seen that half a brick is one-third (0·33) of a brick and a half; one brick is two-thirds (0·66) and so on. It is perhaps the simplest and quickest way to calculate as if the wall were the standard thickness and then to multiply the result by 0·33, 0·66, 1·33 as the case may be.

The following data in connection with the measurement of a rod of brickwork will be found useful:

In one rod there are required:—

272 feet super. at 14 inches (a brick and a half) thick.
408 feet super. at 9″ thick.
306 cubic feet.
11½ cubic yards.
4300 stock bricks.
1 cubic yard stone lime and 3½ cubic yards sand;
or 36 bushels cement and 36 bushels sand.
126 gallons of water.

The total weight is 14 tons.

Also—330 bricks go to the ton.
400 to 500 bricks go to the load.
27 loads of mortar = 1 cubic yard.

The next point of importance is that of preventing damp from penetrating brick walls both vertically and horizontally. As no form of building material is in itself entirely waterproof, the thickening of such in walls can only be a means of putting off the inevitable penetration to a slightly later date. It is necessary therefore to make provision at the outset for the complete prevention of this most damaging element.

Firstly, it is possible to prevent the rise of damp from the soil through the foundation, by insulating the superstructure therefrom by means of a damp-proof course which should be laid throughout the wall both across and along at some little distance—usually 6 or 9 inches—above the ground level. It should be carefully noted

that this layer of damp-proof material should be placed in such a position that any floor timbers are above it and thus insulated with the rest of the superstructure. The most usual and effective methods in this respect are :

1. Tar and sand.
2. Old slates (two courses with joints broken) in cement.
3. Rolls of asphalted felt.
4. British asphalt ½ inch thick.
5. Sheet lead, which, however, is too expensive for farm and estate work.

To prevent the horizontal penetration of damp—as from driving rain—the most usual safeguard is to build the wall in two sections, i.e. in a 9-inch wall, a space or cavity of about 2 inches is left between

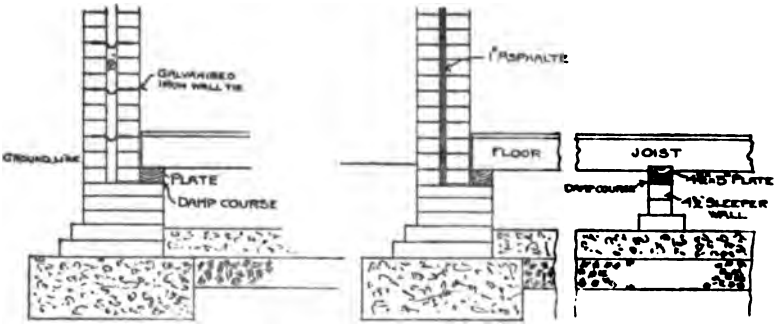


FIG. 180.

the outer and inner sections of 4½ inches each. This checks the damp and prevents it penetrating across the cavity to the inner portion of the wall. Such cavity should be commenced directly above the damp-proofcourse, and naturally necessitates the connecting together of the two sections of the wall. This is usually effected by the use of iron ties, which are built into the two walls at both ends and should occur at the rate of 1 in every 3 feet horizontally and 1 in every 18 inches vertically. The ties should be either bent downwards in the middle or twisted so that the moisture that penetrates the outer portion of the wall shall not be conducted across the ties to the inner portion.

Special stoneware bonding bricks are also used, the outer ends of each being built into a lower course than the inner end. These, however, are more expensive than the iron ties, which should be galvanised, or tarred and sanded to protect them from oxidation. Exactly the same method is used for walls of greater thickness than 9 inches, but the distance from the outside face of the wall to the inside of the cavity should always be the same, i.e. the outer portion

of such a waterproof wall should always be 4½ inches, next to which comes the cavity and according to the necessary thickness of the wall so is it increased, but inwards from the cavity.

A very effective method of waterproofing a wall in connection with the provision of a cavity frequently adopted in better-class work is to leave a cavity of about 1 inch wide which is filled, from time to time as the wall grows in height, with hot liquid asphalt, the internal joints being left fairly void in order to give the material a key to the brickwork.

There are also methods of more or less rendering waterproof walls which are built without cavities, e.g. (1) rough casting, (2) vertical tiling or slating.

In the case of rough casting the bricks can be any sound, well-burnt stocks, irrespective of colour, as such bricks, while quite strong, are usually rough-faced, and this is very useful in helping the rough-cast to adhere. This method—which is also known as 'pebble-dashing' and 'slap-dashing'—is the coarsest kind of external plastering and is very durable if properly mixed. The wall is first plastered with a rough coat composed of 1 part Portland cement and 3 parts of sand, after which gravel, shingle, or other materials, such as spar, broken pottery, &c., are thrown at it while it is soft. If the gravel is mixed and laid with the plaster there is a tendency in laying for it to tear the plaster away from the wall. If lime is substituted for Portland cement it should be weather-resisting and used hot. The face of such work is usually treated with a lime-wash in any colour specially preferred.

Rough-casting or vertical tiling or slating is particularly useful in buildings whose walls are in part or entirely framed in timber. In such cases the outer surface of the timber framing is prepared for rough-casting with lathing and for tiling or slating with battens.

Prices

(Free on rail)

Rough stock bricks	28*s.* to 32*s.*	per 1000
Picked stocks	35*s.* to 40*s.*	,, ,,
Facing bricks	45*s.* upwards	,, ,,
Blue Staffordshire bricks	£3 15*s.* to £4 10*s.*	,, ,,
Stourbridge fire-bricks	£4	,, ,,
Paving bricks	£3	,, ,,
Brickwork in lime mortar	£14 per rod	
,, ,, cement ,,	£17 ,, ,,	
Sand, pit or river	6*s.* to 8*s.* per yard cube	
Best Portland cement	37*s.* per ton or 2*s.* per sack	
Best ground blue lias lime	20*s.* per ton.	
Grey stone lime	14*s.* per yard cube	

Damp courses :	
1. Tar and sand . .	2*d*. per foot super.
2. Slates in cement . .	4*d*. ,, ,, ,,
3. Asphalted felt . . .	2*d*. ,, ,, ,,
4. British asphalt 2 in. thick .	4*d*. ,, ,, ,,
Wall ties	3*d*. to 4½*d*. each
Vertical damp course of asphalt .	8*d*. per foot super.
Rendering, floating, and rough-casting with lime mortar on brick or stone	1*s*. 3*d*. per yard super.
Ditto on lath.	2*s*. ,, ,, ,,
Rendering and rough casting with 1 part Portland cement and 3 parts sand ¾ inch thick . .	1*s*. 9*d*. ,, ,, ,,
Dashing with fine selected shingle .	6*d*. ,, ,, ,,

Stonework.—It is not intended here to go very deeply into the question of building stone, but it is hoped that the important points touched upon may be of service for ordinary farm and estate purposes. To deal exhaustively with so important a department of building would naturally necessitate far greater space than could be devoted to it in a general treatise.

It is of great importance that a suitable stone should be chosen for any work in hand, and one of the most likely faults is the inability to weather well. Durability is to be discovered principally by testing the porosity of a stone by soaking in water for 24 hours. After such treatment the increase in weight should not be more than ½ per cent. in the case of granites, 10 per cent. in the case of standstones, and about 16 per cent. in the case of limestones. There is no reason to suppose that because a stone is hard it will therefore prove durable as a building material, as it is quite possible that a preliminary test with a weak solution of sulphuric acid, or the more practical test of the elements, may prove it to be incapable of weathering well; whereas another stone, which to the casual glance may appear infinitely softer and less durable, may in its structure and composition possess ingredients which make for far greater lasting qualities. To the lay mind it may sound odd and unlikely that such material as stone requires to be seasoned; but such is indisputably the case, as there is a certain amount of sap, or what is known as 'quarry moisture,' which must be got rid of before the stone can be said to be ready for use in building work.

There are four distinct groups in which building-stones may be classified, which are as follows :—

1. Granites which are composed of quartz, felspar, and mica, and as the first-named ingredient is the hardest and most durable of the composition it follows that the granite containing the most quartz is the hardest and most durable building-stone. Granite is used for heavy engineering work, and is found in its best form in Scotland and Cornwall. The production of granite is due to the action of intense heat.

2. Slates are the product of enormous pressure and are close-grained and compact, being composed of silica and alumina. Their formation enables them to be split into thin sheets producing either slabs for use in cisterns, shelves, billiard table beds, &c., or still thinner sheets which are ultimately cut to various sizes for roof coverings. Though useful slates are found in a variety of districts, Wales can claim to have the greatest output of the better qualities.

3. Sandstones are composed of sand, which is bound together by some natural cementing material such as carbonate of lime or magnesia, and their durability greatly depends upon the latter, which may or may not be very subject to elementary action. Most districts can produce sandstone, but the best and most reliable varieties come from Yorkshire—whose best-known quarry, is, perhaps, Bramley Fall—Mansfield in Nottinghamshire, and the most durable of all from Craigleith, near Edinburgh.

4. Limestones are composed of carbonate of lime with a certain amount of silica, and may be either granular in texture or close-grained. As in the case of sandstones, limestones are a common product of this country, but the best known are Bath Stone (from Box and Corsham), Portland Stone, Kentish Rag (which is hard, compact, non-absorbent and difficult to work), and Yellow Mansfield which is useful when carving is desired. Marble is a dense form of limestone which will take a high polish and comes chiefly from Purbeck, Derbyshire, and Devonshire.

The difference in strength between a granite and a limestone will be readily understood by comparing the crushing weight per square foot, which is over 860 tons in the case of Craigleith stone as compared with under 100 tons in the case of Bath Stone.

Stone walls are classified under three headings :—

1. Rubble, which is unsquared and very frequently uncoursed.
2. Block, in course consisting of larger but unsquared blocks of stone laid more or less in a similar way to that adopted in brick walls.
3. Ashlar—that is, large squared and regular blocks carefully laid in courses which vary from 10 to 14 inches in depth.

PRICES

		Per. ft. cube s.	d.
Bath Stone.	Delivered on road wagons. Railway Depot	3	6
Portland Stone	,, ,, ,, ,, ,,	4	6
Mansfield Stone	,, ,, ,, ,, ,,	5	3
York Stone	,, ,, ,, ,, ,, ,,	5	3
Granite (Aberdeen)	,, ,, ,, ,, ,,	8	3
,, (Cornish)	,, ,, ,, ,, ,,	7	0

Concrete Slabs and Bricks.—There is no doubt that concrete can be satisfactorily used in place of stone and brick in the making of walls. In fact, there is a vast number of buildings, both urban

and rural, mainly consisting at the present time of concrete. The urban buildings can, however, be left out of the present question, since by reason of the nature of their use it is usual to combine the material with a great deal of steel in order to fit them for requirements. The particular form of building walls of concrete consists, so far as this volume is concerned, of blocks of varying size. It is possible to divide these into two classes—namely, slabs or blocks, and bricks. A new settlement, whose size is being increased annually, exists in Norfolk where the houses are entirely built of concrete blocks and the roofs made of concrete tiles. So long as the slabs are of reasonable dimensions and capable of easy handling it is not difficult to understand that much time and labour is saved in their use, but whereas these slabs of concrete, set on edge, are capable of standing great strain, let no one run away with the idea that a thin wall of, let us say, 3 or 4 inches will therefore be satisfactory in every way. As far as strength is concerned such a wall is everything that can be desired, but there is the very important question of porosity to be considered. No concrete is waterproof, especially in thin sheets such as these, and it therefore becomes quite as important to provide for this contingency in the present case as in brick and stone walls, if not more so. It will be necessary then to build such walls with cavities as in brickwork and it also will be found necessary very carefully to work out the sizes of slabs or blocks required to form window and door openings and to have the moulds made accordingly. Such work obviously requires the presence of some one whose knowledge and capability is somewhat greater than that which is sufficient to erect a building of brickwork. This necessity, however, should not really be regarded as a complete stumbling block, as with the requisite ability of the man in charge buildings can be fashioned of concrete blocks most satisfactorily.

Moulds of the varying and requisite sizes are first made of wood, care being taken that the inner surfaces which actually mould the wet concrete are either quite smooth or carefully marked with the reverse of the pattern which it is proposed shall appear on the face of the finished blocks. Though taking considerably longer to reach the stage fit for handling in any way, there is no doubt that wet concrete gives better results than dry concrete in these cases. The concrete should be of a fairly fine nature consisting only of the smallest aggregate with sand and cement. The edges of each block should have grooves moulded in them, as the strength of the cement joint between two blocks will be greatly increased thereby. Colouring pigment can be introduced into the mixture of concrete according to individual taste, and by this means the cold, inartistic colour generally seen can be substituted by one which is far more pleasing to the eye, and which harmonises better with the natural surroundings.

There are machines, which can either be hired or bought, for the purpose of making concrete bricks, and it is claimed for them that they can turn out an astonishing number of bricks in a week. This,

of course, is a tremendous asset in districts where ordinary bricks are impossible because of their prohibitive price (which is due to carriage), as concrete bricks can be made very inexpensively by comparison and, except as regards their natural colour, compare very favourably for building purposes with the kiln and clamp burnt variety.

The above-mentioned point regarding porosity and the penetration of damp needs, of course, no consideration where internal partition walls are concerned, and in these positions concrete slabs are actually preferable to bricks, particularly on the score of cheapness and rapidity in use.

A very common form of concrete used in the making of partition blocks is that whose aggregate is coke-breeze or pumice-stone. Either of these materials produces a strong, light concrete, which moulds very satisfactorily into blocks, which can be very easily handled, and, by reason of the great number of minute interstices on the face of the blocks when set ready for use, plaster can be made to adhere even more readily than upon the face of brickwork. The cost of these blocks built into position is usually about 2*s*. per yard super.

Concrete Upper Floors

As has already been mentioned, it is possible to substitute concrete for other material in a variety of ways. It is none the less true with respect to upper floors. It will be readily understood, however, that since the expense of such is greater than that of timber floors, the material in question can really only be considered when the importance of the work in hand merits extra outlay. There are, in fact, very few occasions when such extra expense can be entertained, but there is no doubt that satisfaction follows the taking of such as step in connection with the upper floor of the North Range when the size of the farm requires the outlay of some thousands of pounds in buildings and equipment. The two main points in favour of the use of concrete in the making of such floors are firstly, its fireproof propensities, and, secondly, its imperviousness to vermin, and therefore, to uncleanliness.

In contradistinction to the composition of concrete in such positions as foundations, floors on the ground level, &c., it is desirable nay, even necessary, that it should be kept as light as possible where it has to be supported in spans over the room beneath. This effect is obtained by choosing for the aggregate such material as pumice-stone, coke-breeze, or fire-brick—the first two being eminently fire resisting and light to boot.

Although the concrete arches may quite well be carried on timber girders at their springing, it is a wise precaution to eliminate from the construction all materials which are not fireproof. The supports should therefore be of steel in the form of girders between which either brick arches may be built carrying the concrete floor, or the concrete itself may be laid direct upon the timber centering,

which, of course, must be previously fixed, so that, when it is stripped off after the concrete has set, the latter will assume the correct arch form on the under side. The arched system of concrete floors is sufficient to deal with in connection with farm and estate buildings, being perfectly satisfactory for the purposes required without being prohibitive in cost. Nevertheless, it may be stated that there are other systems of concrete and steel floor construction in several forms, the most recent and best known being what is called reinforced or armoured concrete. In this form of construction steel bars of varying diameter and shape are introduced into the body of the concrete, welding, together, both girders and floor into one homogeneous mass.

The Arched Concrete Floor is in idea very similar to the usual type of double timber floor specified for important positions, such as granaries, &c.—that is to say, the main forms of support are laid at intervals varying, according to circumstances, between 6 and 10 feet apart, and having their bearing upon the walls at both sides.

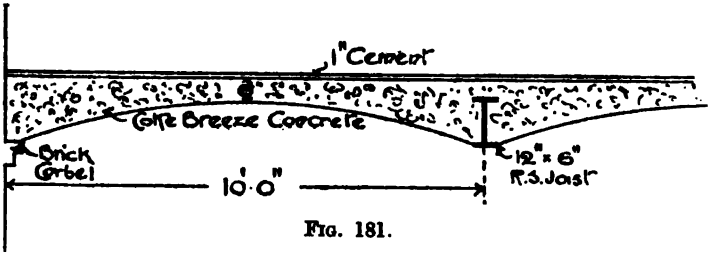


FIG. 181.

Between these girders lie the sections which go to make up the total area of the floor, and which are composed of arched concrete, usually rendered on the upper side with cement, to provide a neat and clean finished surface. It is as well, in order to carry out as fully as possible the intentions towards cleanliness, to round the cement up where the floor meets the walls, so that all sharp corners are done away with, and the chances of the collection of what is, or may be, unclean yet further lessened. Since such floors are naturally considerably greater in weight than their timber prototypes, the weight that is concentrated at the points where the girders bear on the walls requires extra provision. This, however, is not a serious matter and can be dealt with by slightly increasing the dimensions of the brick piers which have to be provided in any case where a considerable load is concentrated and superimposed upon the walls at different points.

ROOF COVERINGS

This question naturally covers a very large and varied choice of materials, each of which has its value in the different positions and circumstances which are met with when considering farm and

estate buildings. The most important and usual are dealt with individually as follows.

Slates.—Usually the thinnest are the best, the most usual sizes being:

Ladies	16″ × 8″
Viscountesses	16″ × 10″
Countesses	20″ × 10″
Marchionesses	22″ × 12″
Duchesses	24″ × 12″

The average pitch of slated roofs is from 25° to 30°, according to the size of slates, the smaller sizes requiring the steeper pitch. They are hung with two nails, usually at the head, but sometimes in the centre. The 'lap' is the distance that one slate extends over the next but one beneath it, and varies, according to the exposure to which the roof is to be subjected, between 2½ and 4 inches. The 'gauge' is the distance apart of the battens to which the slates are nailed, and of course varies according to the necessary lap. Slates may be nailed either to battens or to rough boarding, in which case what is called sarking felt is laid on the boarding before laying the slates. In order to find how many slates are required to cover a roof of stated area, divide the area of the exposed portion of one slate into one square (which is 100 square feet) and multiply the result by the number of squares of roofing to be laid. A certain percentage —say 5—should be added per square for waste and breakages. At the junction of two slated slopes, either at the ridge or hip, it is usual to fix ridge-tiles and bed them in cement. Cement alone may be used as a ridge covering, being carefully finished in an even width and continuous jointless length. The absence of joint is a point in favour of this method, but the cement is liable to crack and altogether is not as satisfactory as ridge coverings such as have been mentioned above. In the case of valleys it is necessary to form the connection of lead which is shown in another chapter.

Tiles are made of similar material to that of bricks but rather finer. Plain tiles measure 10½″ × 7″ × ½″ and benefit by having a slight curve in their length, which helps them to bite well on to each other. Holes for nails are made in the head before the tile is burnt and their fixing on the roof is similar to that of slates as regards battening, lap, &c. Frequently, however, wooden pegs are driven into the head holes and the tiles are hung instead of being fixed. In the latter case particularly, and frequently in any case, lime and hair mortar is used for bedding the tiles and forms an extra safeguard. In order to break the joint verge tiles are made the width of a tile and a half. Instead of nail or peg holes, a great many tiles are made with nibs or projections on the under side of the heads by which they are hung to the battens.

Pantiles are of flat S-shaped section and are used in inferior work and measure 14″ × 9″ × ½″. By the method of laying, wherein the upper curve of each tile overlaps the lower curve of the

next, a series of channels or gutters is formed and extends from the ridge to the eaves, conducting rain-water away at once with a minimum chance of leakage. This type of tile, however, is only used for piggeries, outhouses, and the like. As all tiles are more absorbent than slates it is necessary that they should not be laid at a flatter pitch than 45°.

Asbestos cement tiles are put on the market at the present time by a great many firms, and are all very similar. There are sundry points in favour of this type of roof covering. The tiles are the reverse of brittle, eminently poor conductors of heat and cold, inexpensive, very little more absorbent than slates (which means that a flat pitch is possible), extremely light (which reduces the cost of roof timbers), and do not offend the eye. They can be procured in varying sizes up to about 2 feet square, and being smooth and even in manufacture they lie very flat together, forming good joints. Though they would scarcely be suitable for better-class work, such as moderate-sized residences, there is everything in favour of their use where economy has to be studied.

Concrete tiles can be bought or home made, either by hand, in a mould, or by machine. The material for their composition must of necessity be fairly fine, and it is desirable that their exposed faces should be reasonably smooth. They can, of course, be made to any size to suit requirements and are about $\frac{1}{2}$ to 1 inch thick, being moulded with either ribs for hanging or nail- and peg-holes.

Corrugated iron sheets are an exceedingly satisfactory form of roof covering in the case of temporary or unimportant erections, owing to the rapidity with which they can be fixed or taken down and refixed. The sheets vary from 6 to 8 feet in length and 2 to 3 feet in width, and are fixed with galvanised iron nails driven through punched holes to the timber bearers, which are spaced apart so that the sheets are fixed at two points, the bearers running at right angles to the sheets. The vertical lap is usually about 6 inches and the horizontal lap one corrugation. Where metal bearers are provided the fixing is made with small bolts and nuts. Owing to the impenetrability of their surface to moisture corrugated iron sheets can be laid practically flat if desired, but on the other hand the conductive nature of the metal renders roof boarding necessary for any building which should be kept cool in summer and warm in winter. Uncorrugated pieces are procurable for covering ridges, hips, and valleys.

Thatch is a material whose vermin and fire-attracting nature removes it from contemplation for any other purpose but that of effect. As this and its non-conductivity are, perhaps, its only assets, it is not proposed to dwell upon any explanation herein.

Patent roof coverings, in the form of rolls of material whose composition consists largely of rubber, distinctly have their uses, and can be obtained in various qualities. In their favour can be urged inexpensiveness, rapidity of fixture, lightness and non-conductivity, but although it is claimed for them by the several patentees

that they possess great lasting qualities, the better class of building will be better served by being roofed with one of the first few materials mentioned. Again, in this case roof boarding is a necessity, which is an expense which can well be avoided by the choice of slates, patent or otherwise, and tiles as roof coverings.

Prices

		£	s.	d.
Slates. Delivered at Railway Depot				
20″ × 10″. Best Blue Welsh	per 1000 of 1200	13	2	6
16″ × 8″ ,, ,, ,,	,, ,, ,, ,,	7	5	0
Tiles. Delivered at Railway Depot.				
Best plain red roofing . . .	per 1000	2	2	0
,, Broseley	,,	2	10	0
Hip and valley tiles . . .	per dozen	0	3	7
Pantiles	per 1000	3	15	0
Glass tiles	each	0	1	4
Asbestos cement tiles with felt	per square fixed	1	15	9
Corrugated Iron.				
Per foot super. 16 gauge. . .	free on rail	0	0	9½
18 ,, ...	,, .	0	0	7½
20 ,, ...	,, .	0	0	6½
22 ,, ...	,, .	0	0	5½
Ruberoid (3 feet wide by 72 feet long inclusive of accessories necessary for fixing—to cover 2 squares of roof)	free on rail	17*s.* 4*d.* to 34*s.* 6*d.*		

CHAPTER XVII

TIMBER: CARPENTER'S AND JOINER'S WORK

Timber

It will only be found necessary to consider quite a few of the possible different sorts of building timber, and these are practically represented by Baltic or Northern Pine, spruce, pitch pine, and oak. Of these, as will be seen from the following list, oak is what is known as a hard wood, the others being soft woods, a condition governed by their resinosity.

Soft Woods [1]

Name	Uses	Weight per c. ft.	Price per c. ft.
		lb.	s. d.
Red or Yellow Fir or Northern Pine (*Pinus sylvestris* or Scots Pine).	General Carpenter's work. Best for joinery.	31	2 0 *to* 2 6
American Pine (*Pinus rubra* or Canada Red Pine).	Joinery.	40	3 0
Pitch Pine (*Pinus rigida*).	Heavy engineering structures, also for ornamental joinery.	45	2 6
Spruce (*Abies excelsa* or White Fir).	Common joinery and floors.	37	2 0
	Hard Woods		
English Oak.	Where strength and durability are required.	53	6 0
American and Dantzic Oak.	As above, but is not as strong.	45	4 6
Beech.	Piles, wedges, and carpenter's tools.	53	3 6
Ash.	Tool-handles.	52	4 6
Elm.	Piles and various carpenter's purposes.	42	4 0

[1] The following figures, which are for seasoned wood, can only be taken as a guide, as they are subject to variation. Prices are published weekly in the building journals.

Hard woods—continued

Name	Uses	Weight per c. ft. lb.	Price per c. ft. s. d.
Mahogany.	Ornamental joinery.	66	9 0 *to* 11 0
Teak (Indian Oak).	Treads of steps, floors, &c.	47	11 0

Market Forms of Timber.—Logs are trunks of trees with the branches lopped off.

Baulks are the trunks which have been roughly squared.

Planks are pieces 2 to 6 inches thick, 11 to 12 inches wide, and 8 to 21 feet long.

Deals are similar to planks, but 9 inches wide and not more than 4 inches thick.

Battens are similar to deals, but only 7 inches wide.

Qualities in Timber.—The time taken in growing governs the density of timber.

The lowest part of the tree produces the strongest timber.

The sap should all be removed in satisfactory building timber.

Heart and star shakes are cracks radiating from the heart.

Cup shakes appear between, and separating, the annual rings.

Dry Rot is caused by insufficient ventilation and a certain temperature combined, and is a fungoid growth.

Wet Rot is caused by exposure for any length of time to moisture.

A load of timber is 40 cubic feet of logs or unsquared, and 50 cubic feet of squared, timber.

A Petersburg standard contains 165 cubic feet.

A London standard contains 270 cubic feet.

120 deals = 100.

The following lists of marks are useful to remember:

Swedish timber is stencilled on the end with RED letters or marks.

Russian or Finnish timber is 'dry stamped' or 'hammer branded,' producing small, uncoloured letters about 1 inch long.

Norwegian timber is stencilled with BLUE letters.

Canadian timber is stencilled with BLACK letters.

All timber for building purposes has to be seasoned, the result of using timber too soon after felling being that it twists and warps out of shape. Such defects are particularly noticeable in such imported finished articles as doors, windows, &c., from whose price, however (which is extremely low), such results can only be expected. Seasoning is effected by natural means, i.e. by stacking in such a way that the air can circulate freely. There are artificial methods of seasoning, such as hot air, boiling and steaming, which, however, are not as satisfactory as the natural way.

Preservation of timber can be effected in a variety of ways, such as the application of paint, tar, varnish, &c., and when the timber has to be used in unexposed or damp positions such methods as creosoting (immersion or impregnation with oil of tar), kyanising (impregnating with corrosive sublimate), burnetising (impregnating with burnettizine or chloride of zinc) are extremely effective, and when thoroughly done in the case of properly seasoned timber have a lasting effect. About 6 lb. of creosote will satisfactorily impregnate 1 cubic foot of fir timber. The best time for felling is at a season when the sap is at rest—i.e. during the winter months.

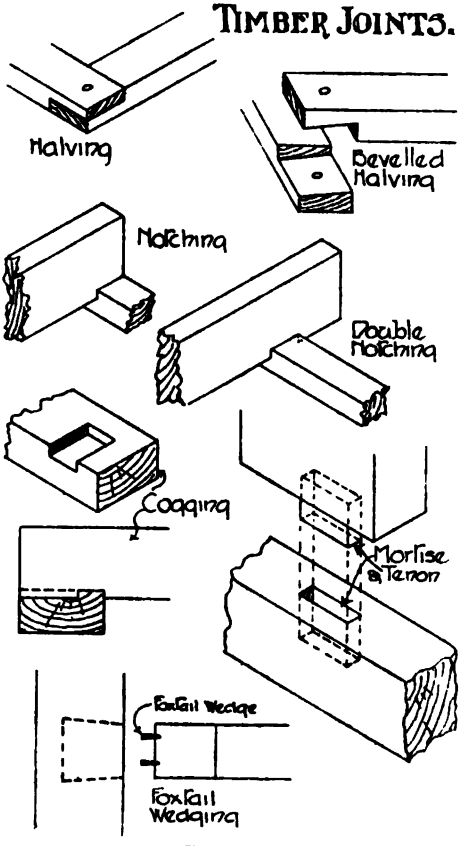


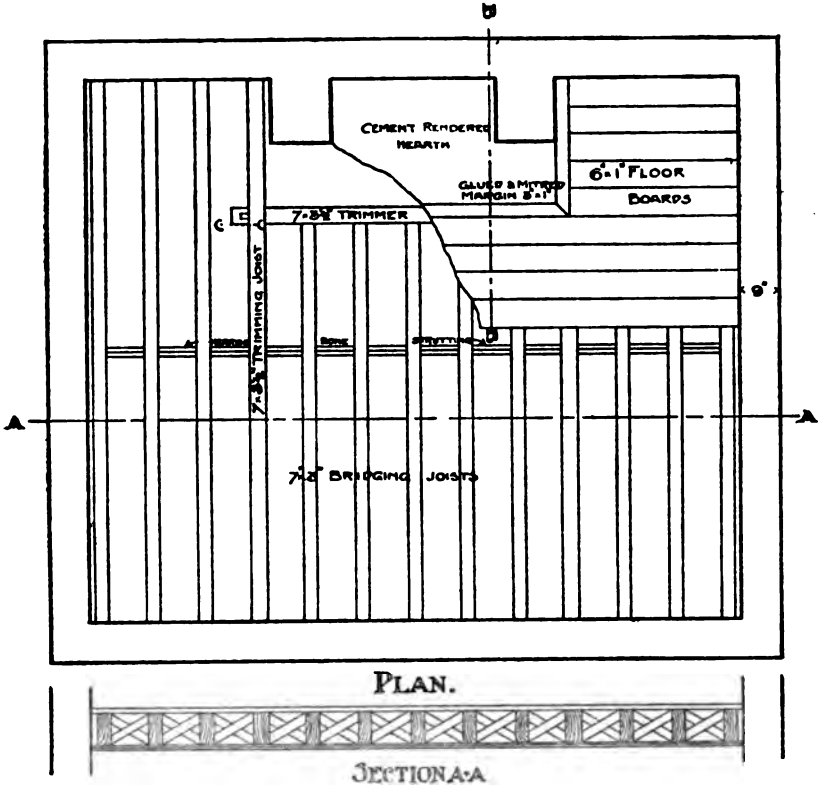
FIG. 182.

Joints.—In the multitude of points in which timbers have to be jointed together when constructing a building the greatest amount of care has to be taken in assuring their perfect efficiency, and for the various purposes required a number of different methods have been evolved during the process of time. In order to understand these thoroughly a knowledge of practical carpentry is distinctly advisable, although a fairly good idea can be gathered from the accompanying diagrams, illustrating at any rate those which are most common. These various joints will be met with repeatedly, not only in illustrations of different timber work, but, of course, also in practice.

FLOORS

For all practical purposes floors may be classified under three headings: (1) Single; (2) Double; (3) Framed.

Single floors are, of course, the least intricate in construction and are sufficiently strong for moderate spans—i.e. up to about 16 feet—


CEMENT RENDERED HEARTH
GLUED & MITRED MARGIN 8"×1"
6"×1" FLOOR BOARDS
7"×3½" TRIMMER
7"×3½" TRIMMING JOIST
7"×2" BRIDGING JOISTS
9"
PLAN.
SECTION A-A

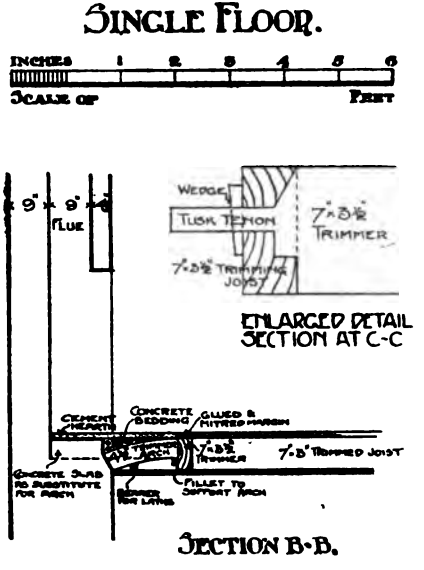

SINGLE FLOOR.
INCHES 1 2 3 4 5 6
SCALE OF FEET
9" 9" 9"
FLUE
WEDGE
TUSK TENON
7"×3½" TRIMMER
7"×3½" TRIMMING JOIST
ENLARGED DETAIL SECTION AT C-C
CEMENT HEARTH
CONCRETE BEDDING
GLUED & MITRED MARGIN
7"×3½" TRIMMER
7"×3" TRIMMED JOIST
CONCRETE SLAB TO SUBSTITUTE FOR ARCH
FILLET TO SOFFIT OF ARCH
SECTION B-B.

FIG. 183.

and are composed of joists which extend from wall to wall—into which they are built—across the shorter of the two superficial measurements. Thus if a space of 20 foot long by 10 feet wide has to be floored the joists would be laid across the 10-foot way, and, as a general rule, 12 inches apart from centre to centre. The floor boards are then laid at right angles to the joists and forced together by mean of a cramp and nailed down into position. Where the under side of the floor is to be provided with a ceiling to the room underneath, the boards or lath and plaster used for this purpose are usually attached to the under side of the joists. In better-class work, however, separate ceiling joists are provided and fixed independently of the floor joists above, thus ensuring the ceiling against damage due to cracking when any possible great increase of weight is superimposed on the floor above. These ceiling joists are usually 2 inches thick and ½ inch deep for each foot of span, the minimum depth being 3 inches. In order to stiffen the floor joists a series of

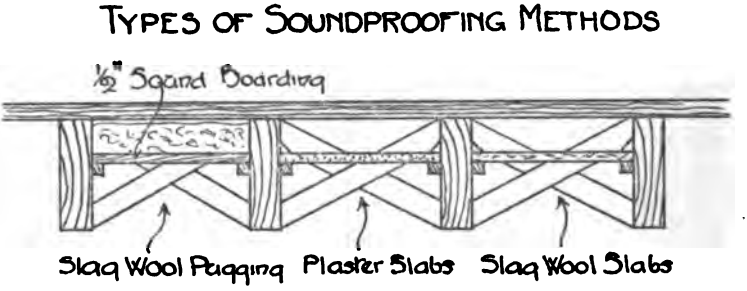
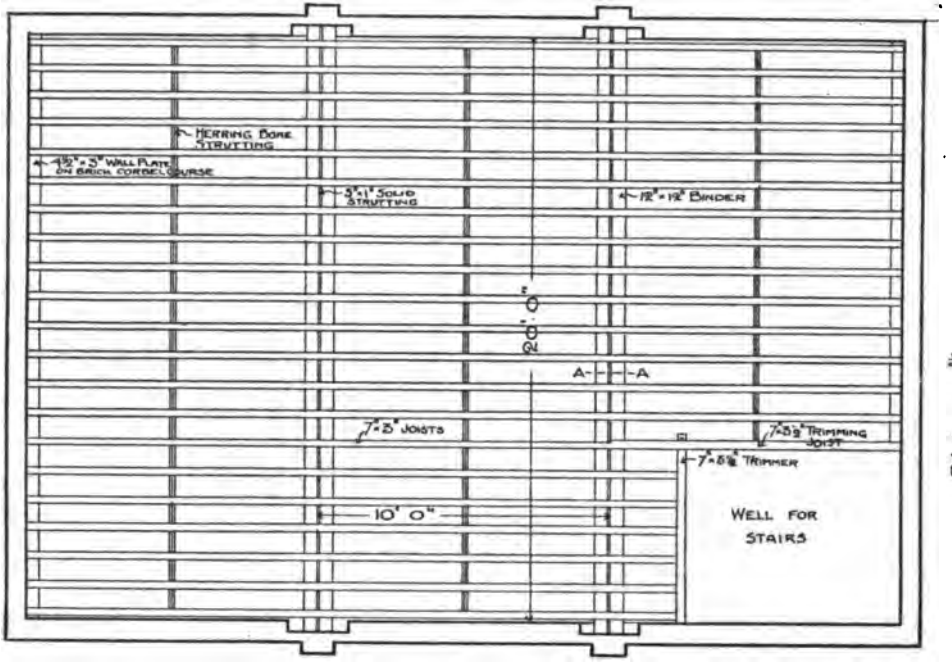


FIG. 184.

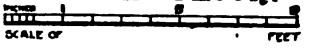
herringbone strutting should be introduced, so that no greater length than 6 feet is unsupported in this way.

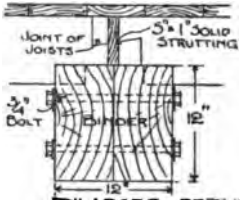
It is desirable, if the expense can be afforded, to render floors sound-proof. This is effected either by (1) Separate ceiling joists; (2) Felt which is nailed to the top of the joists before laying the floor boards; (3) Sound boarding and pugging as shown in the diagram—the pugging being composed of silicate cotton or similar material; or (4) Special slabs of slag wool sandwiched between wire-netting 1 inch thick and attached to the under side of the joists—the ceiling being laid immediately on the under face of the slabs. (See Fig. 184.)

In the case of ground floors, the scantling of the joists may be considerably reduced by the provision of what are known as sleeper walls about 6 feet apart built at right angles to the joists. It therefore follows that no area is too great for a single floor so long as it is on the ground level and has sufficient sleeper walls to lessen the span of the joists. The sleeper walls are provided with wall plates as their topmost members, which are bedded on the bricks

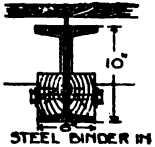


DOUBLE FLOOR.





ENLARGED DETAIL SECTION AT A-A



STEEL BINDER IN PLACE OF TIMBER

FIG. 185.

in cement or lime mortar, and the joists are spiked to them. (See Fig. 180.)

Any openings which have to be left in floors—as for hearths and well-holes for staircases—require special treatment, and, as will be seen and understood from the accompanying plans, the joists have to be trimmed and supported with what are called trimmers, which in their turn are supported by trimming joists. Both of these necessarily carry extra weight and therefore must be made a little wider than the ordinary floor joists. This increase in width is generally reckoned at $\frac{1}{8}$ inch extra for every trimmed joist. The most usual type of joint used to secure the latter to the trimmer and the trimmer to the trimming joist is that known as a 'tusk tenon and mortise,' as illustrated in the diagrams of the Single Floor.

Where floor boards meet stone, tile, or concrete hearths, &c., they should be provided with glued and mitred margins, as shown. The thickness of these margins should be equal to that of the floor boards and 3 or 4 inches wide.

At the point where the floor boards meet the walls, boards with square, chamfered, or moulded edges, called skirtings, are usually fixed to cover this joint neatly. (See Fig. 193.) The depth of the skirting naturally varies in different classes of work, and can be from 6 inches upwards, and from $\frac{3}{4}$ inch to $1\frac{1}{4}$ inch thick. The best method of fixing is by nailing to a horizontal ground fixed to the wall just below the top of the skirting and rebating the lower edge into a groove in the floor boards.

Double floors differ from single floors in that there are two sets of bearing timbers. The joists being supported upon binders, and, as the latter support the entire weight of the floor, they are laid across the width of the room, the joists being laid upon and at right angles to them, having a cogged-and-spiked joint to keep them in place. The binders are usually laid from 8 to 10 feet apart and are specially built into the walls at each end in a similar manner to the tie-beam of a truss—i.e. on stone or concrete templates. Usually the wall has to be strengthened where the binders are built in, and such is done by building brick or stone piers in the necessary positions.

Thus the floor is divided up into bays, each of which can be considered separately when calculating the scantling of the ordinary floor joists. As for the scantlings of the binders the following will be found useful for reference :—

Clear span	Width of binder	Depth of binder
10 feet	8 inches	8 inches
12 ,,	10 ,,	6 ,,
14 ,,	10 ,,	8 ,,
16 ,,	11 ,,	8 ,,
18 ,,	12 ,,	$7\frac{1}{2}$,,
20 ,,	$9\frac{1}{2}$,,	12 ,,

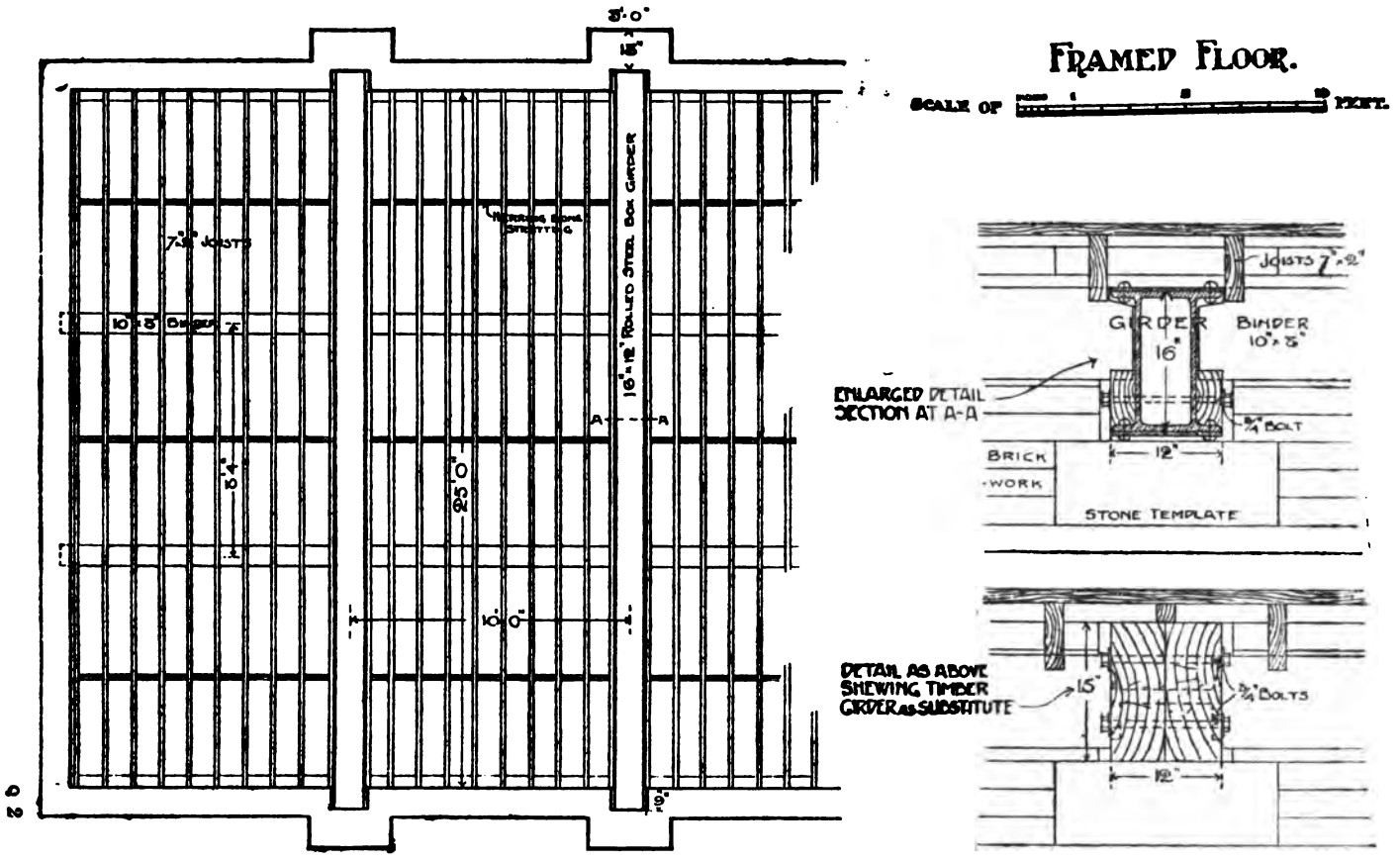
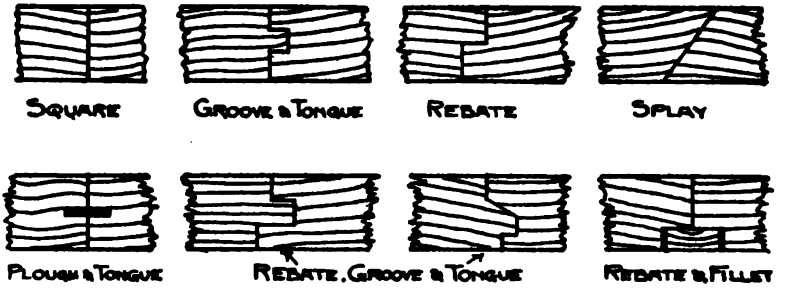

FRAMED FLOOR.
SCALE OF FEET.
7"×3" JOISTS
10"×5" BINDER
16"×12" ROLLED STEEL BOX GIRDER
25'-0"
10'-0"
5'-0"
A
A
ENLARGED DETAIL SECTION AT A-A
JOISTS 7"×2"
GIRDER
BINDER 10"×5"
16"
¾" BOLT
12"
BRICK WORK
STONE TEMPLATE
DETAIL AS ABOVE SHEWING TIMBER GIRDER AS SUBSTITUTE
15"
¾" BOLTS
12"

FIG. 186.

For floor joists :—

6	feet	6	inches	2	inches
8	,,	7	,,	3½	,,
10	,,	7½	,,	2½	,,
12	,,	8½	,,	2½	,,
14	,,	9½	,,	2½	,,
16	,,	10½	,,	2½	,,
18	,,	12	,,	2½	,,
20	,,	12	,,	3	,,

Framed floors have yet one more additional set of bearing members, which can be either of timber or of steel—usually the latter. This additional or third set of bearers again reverses the direction of the floor joists. Since the girders will now support the entire weight of the floor they are laid across the width of the room, supporting the binders which are laid at right angles to the girders. The method of construction in each case will be seen from the accompanying plans. In double and framed floors, where the weight is concentrated upon the side walls at only a few points, care must be taken that solid wall exists vertically downwards from those points as such openings as windows and doors materially reduce the supporting strength of the wall.



TYPES OF FLOORING JOINTS

FIG. 187.

There is a variety of possible ways of jointing floor boards according to different ideas and circumstances. These are shown in the accompanying diagrams (Fig. 187). It should be borne in mind that when timbers, such as floor joists, purlins, rafters, &c., are laid over several points of support their capacity for carrying any superimposed weight is about twice as much as when cut into short lengths.

Table of Scantlings for Timber Girders

Clean span	Width of girder	Depth of girder
10 feet	10 inches	7½ inches
12 ,,	11 ,,	8 ,,
14 ,,	12 ,,	8 ,,
16 ,,	12½ ,,	10 ,,
18 ,,	13 ,,	11 ,,
20 ,,	14 ,,	11 ,,
24 ,,	16 ,,	11 ,,
26 ,,	16 ,,	13 ,,

The usual weights to which floors are subjected are as follows :—

Ordinary dwelling houses . . .	1½ cwt. per foot super.
Workshops and public halls . . .	1½ ,, ,, ,,
Heavy goods stores and factories . .	2½ ,, ,, ,,

Prices	1 inch thick	1¼ inch thick
Deal flooring, rough ploughed and tongued . .	21*s.* 6*d.* per square	26*s.* per square
Oak Flooring . . .	90*s.* ,,	100*s.* ,,
Pitch Pine	44*s.* ,,	50*s.* ,,
Sound Boarding on fillets .	21*s.* ,,	

Single floors, including plates, joists, floorboards and skirtings . . . . . 90*s.* per square

Double and Framed Floors the same, adding cost of binders and girder.

	¾"	1"	1¼"	
Skirtings, square .	7*d.*	8*d.*	9*d.*	per foot super
,, moulded .	8*d.*	10*d.*	1*s.*	,, ,, ,,

Herringbone strutting	4*d.* per foot run
Pugging, 2 inch thick coarse stuff . .	6*s.* per square
,, wirework slabs . . .	1*s.* 3*d.* per yard super.
Glued and mitred hearth borders . .	4½*d.* per foot run

Roofs

In deciding upon the roof with which any building is to be covered, the construction thereof practically depends upon two things: (1) The span; (2) The nature of the material to be used for covering. In respect of the first point it will be readily understood that as the span increases so will it be necessary to make more adequate provision for the support of the roof.

The lean-to roof is the simplest form and requires but little explanation, as it consists only of rafters 3 or 3½ inches by 2 inches, laid about 12 inches apart, and secured at both ends to wall plates set in or upon the walls. Such a roof is sufficiently strong for a span of 8 feet, but for a greater span a purlin should be added,

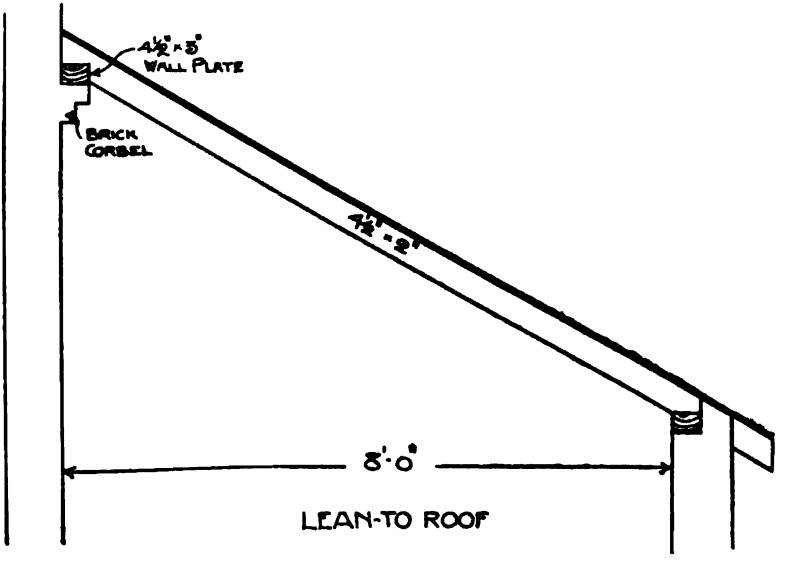


Fig. 188.

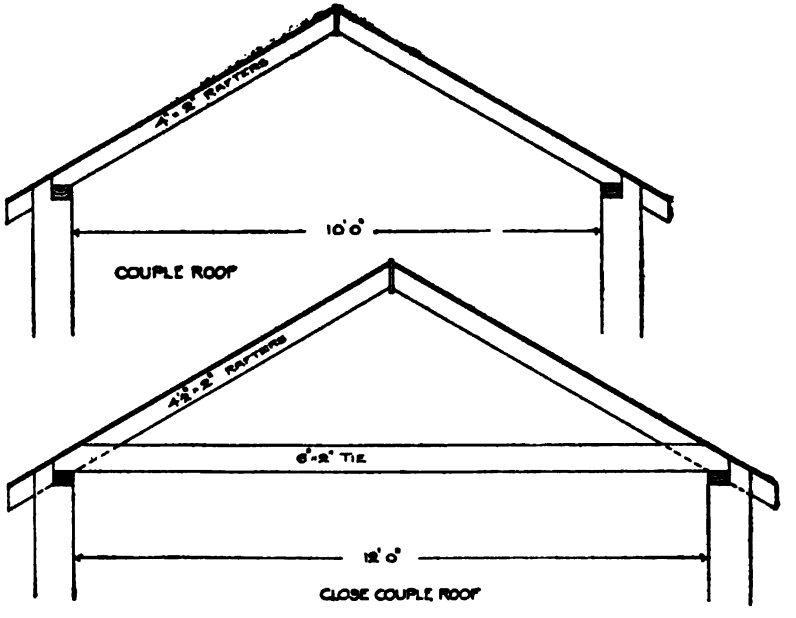


Fig. 189.

which will act as a midway support for the rafters, and is laid at right angles thereto, and rests on the wall at each end. The purlin should be about 6 inches by 4 inches.

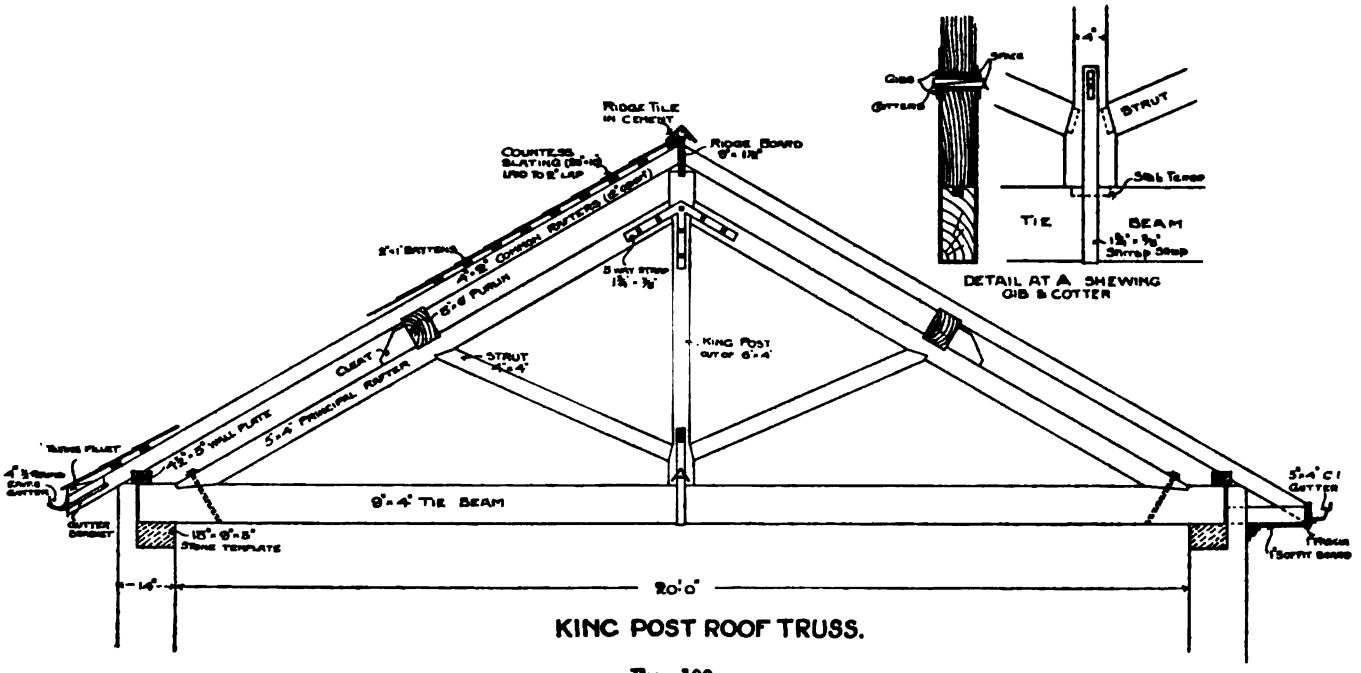
Couple roofs are those in which the rafters rise similarly from each side wall and meet on either side of a ridge board, their pitch having, of course, previously been decided upon according to the nature of the proposed covering. For a span of 12 feet such a roof will stand perfectly well, and the rafters would be 4 inches by 2 inches.

Couple-close roofs are in construction similar to couple roofs, except that they are strengthened by the addition of light tie-beams which secure the foot of each rafter with that of the one opposite and are fixed immediately above the wall plate. When the span exceeds 12 feet purlins are introduced as before so that no length of rafter is left unsupported for a greater distance than 8 feet.

Collar-beam roofs are similar in idea to the last named, but instead of the ties being fixed at the feet of the opposing rafters they are placed about halfway up, which allows of greater height in a room. This type of roof is particularly used in small houses and cottages whose first floor rooms having ceilings which are partly sloping. The foregoing roofs can be used up to a span of 18 feet as explained, and an example of a collar-beam roof will be found in Fig. 216. When the span is greater than 18 feet it is advisable to provide much greater support, and this is done by a truss which is triangular in form and occurs at points varying from 8 to 10 feet apart. Trusses act as supports to the roof by supporting the continuous purlins and ridge board.

The King Post Roof Truss is the first and simplest type, consisting of a horizontal timber—the tie-beam—from which at each end the principal rafters start at the angle at which the roof is to be, and meet the head of the central or vertical member—the king post. Additional support is provided at the points where the principal rafters carry the purlins by the introduction of struts. The tie-beam is built into the wall and rests upon a stone or concrete template whose function is to spread the weight of the roof which the truss imposes on the wall. As shown in the drawing of the king post roof truss (Fig. 190), the principal rafters and the head of the king post are secured together on both sides by a three-way iron strap in addition to the mortise-and-tenon joints. Again at the foot of the king post extra security is provided in its junction with the tie-beam by another iron strap. This joint, which is also mortised and tenoned, can be tightened up at any time by means of the wedges which, as will be noticed in the drawing, are provided in the slot cut at the top of the iron strap.

For spans of from 30 to 35 feet it is advisable to again increase the strength of the truss by the introduction of two queen posts in the place of one king post. Roughly, the queen post roof truss may be considered as a king post truss which has been cut vertically and transversely in half, the two halves separated according to the



KINC POST ROOF TRUSS.

Fig. 190.

span and the spaces thus left between the heads and feet of the two halves of the king post filled in with extra length of tie-beam at the feet and what is called a straining beam at the heads. It will also be seen from the roof truss in Fig. 185 that an extra purlin is introduced at the head of each queen post whose lowest point coincides with the back of the queen post and the upper side of the straining beam. Both in the king post and queen post trusses the purlins are afforded some means of support at the sides where they pass over the trusses in the shape of wooden blocks called cleats and firmly spiked to the timbers upon which they rest. The three-way straps at the queen post heads and the lower straps round the tie-beams are used as in the king post truss. In a great many cases the span and necessary scantling of the tie-beam in a

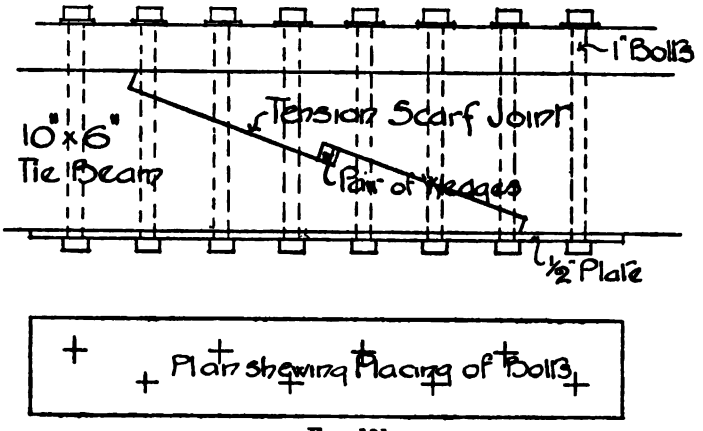


Fig. 191.

queen post truss renders that member extremely expensive, in which case it is possible to obtain quite satisfactory results by making the tie-beam in two halves which can be jointed together in one or two different ways, the most usual and effective being the *tension scarf joint* wherein the line of the joint is sloping and the bolt holes made to coincide by means of a pair of wedges in the centre. The bolts should never be put in centrally in a row, as the plates upon which the nuts are tightened are thus liable to buckle down that line. Alternate spacing as shown in the diagram (Fig. 191) should be chosen.

The roof truss in Fig. 183 differs from the true king post truss, in that the king post is replaced by an iron king rod provided with a helmet or cap into which fit the principal rafters. This form of truss, which will be readily understood from the drawing, has the merit of being cheaper than a king post truss, and is also more efficient.

Although timber roof trusses can quite satisfactorily be used in cases where the span is 40 feet or even more, it is advisable for all

spans over 35 feet, and particularly in the case of farm buildings, to abandon timber in favour of steel, which form of roof truss is dealt with in another chapter.

There are, however, several ways of combining the two materials and forming what are called composite trusses whose name is legion, as they may be more or less constructed to suit individual circumstances.

(For the treatment of rafters in the case of windows rising out of the roof slope and of louvres, see Windows, p. 245, and Louvres, p. 246.)

Doors

There are various possible forms in which doors can be made, but it will only require a very little experience to know which to specify according to requirements. As they vary in construction from extreme simplicity to more intricate form it is only natural that they increase in cost.

A Ledged Door which is suitable for outhouses, earth closets, &c., is formed of horizontal ledges to which the battens or boards are nailed. These are usually $\frac{3}{4}$ inch or 1 inch in thickness and the battens have a longitudinal joint with each other, being grooved and tongued together. The opening in the wall must first be provided with a door-frame consisting of vertical posts and a head piece called the lintel, all usually of $4\frac{1}{2}'' \times 3''$ timber having a rebate into which the door fits. In cheaper work it is possible to use posts and lintel about $2\frac{1}{2}$ inches thick, and to form the rebate by nailing a slip about $\frac{1}{2}$ inch thick along them. The door is then hung to one of the posts by means of cross garnet hinges, the other post being utilised for the fastening catch or bolt staple.

A Ledged and Braced Door is similar in construction to the above, but is made stronger by the addition of diagonal braces, whose feet should be on the hanging side of the door, and the heads on the opposite side. This affords the greatest amount of strength by strutting up the side of the door, which, by reason of its not being fastened or supported in any way tends to drop. The joints of the braces with the ledges should be noticed. A very usual method of securing door and window frames to the walls is by driving galvanised iron holdfasts into wood blocks or breeze bricks, which have been built into the jambs of the openings at certain points. The holdfasts are made with flat heads centrally drilled to form screw holes.

It will be noticed that neither of the preceding types of doors has any framing and their existence is entirely dependent upon the securing of the battens to the ledges, without either of which they could not stand at all.

A Framed and Braced Door is the first of a stronger, more expensive and serviceable type of door, and, as will be seen in the diagram, is composed of two vertical and three horizontal members which are framed together with mortise-and-tenon joints, and upon which the door is primarily dependent for its ability to open and shut, the

Farm Doors.

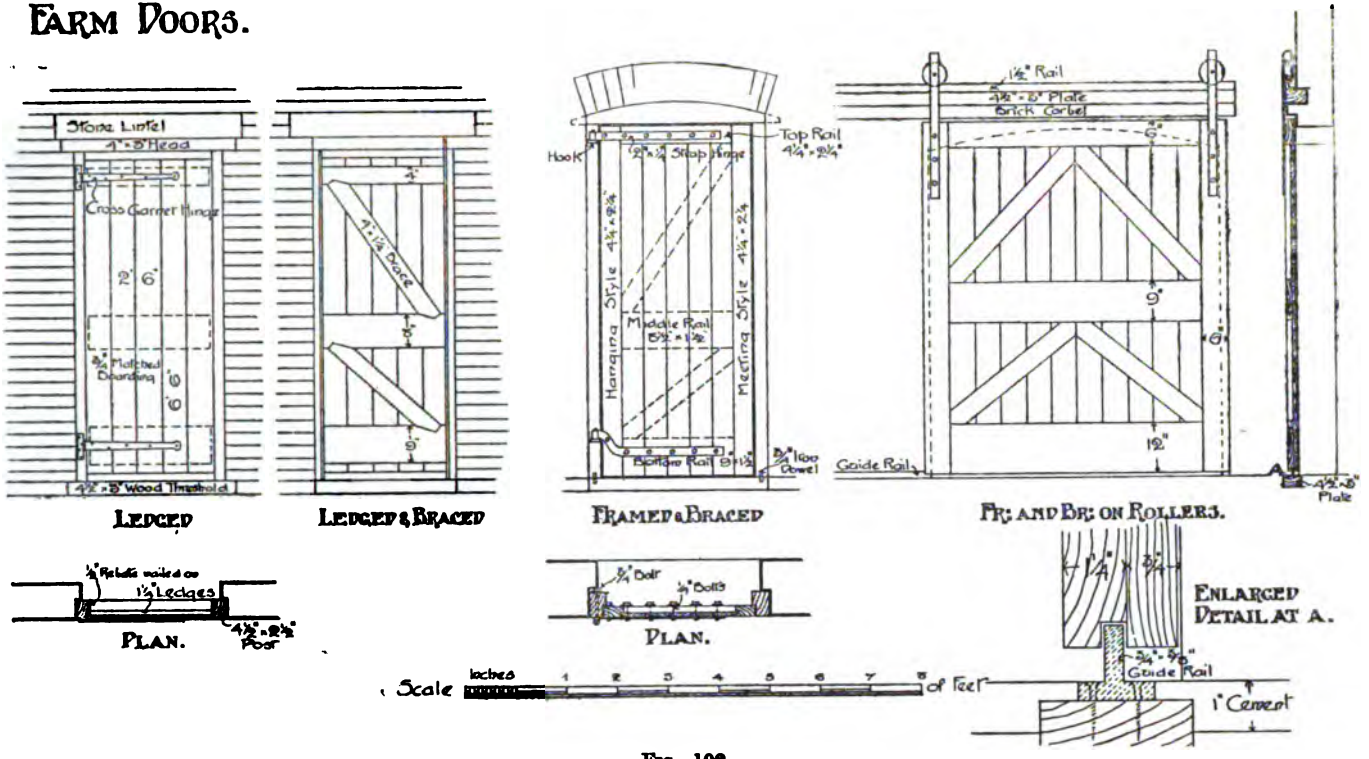


Fig. 192.

braces being added merely for extra strength, and the battening in order to render it sight- and weather-proof. This is the type of door most frequently specified in farm buildings, and as it, and all

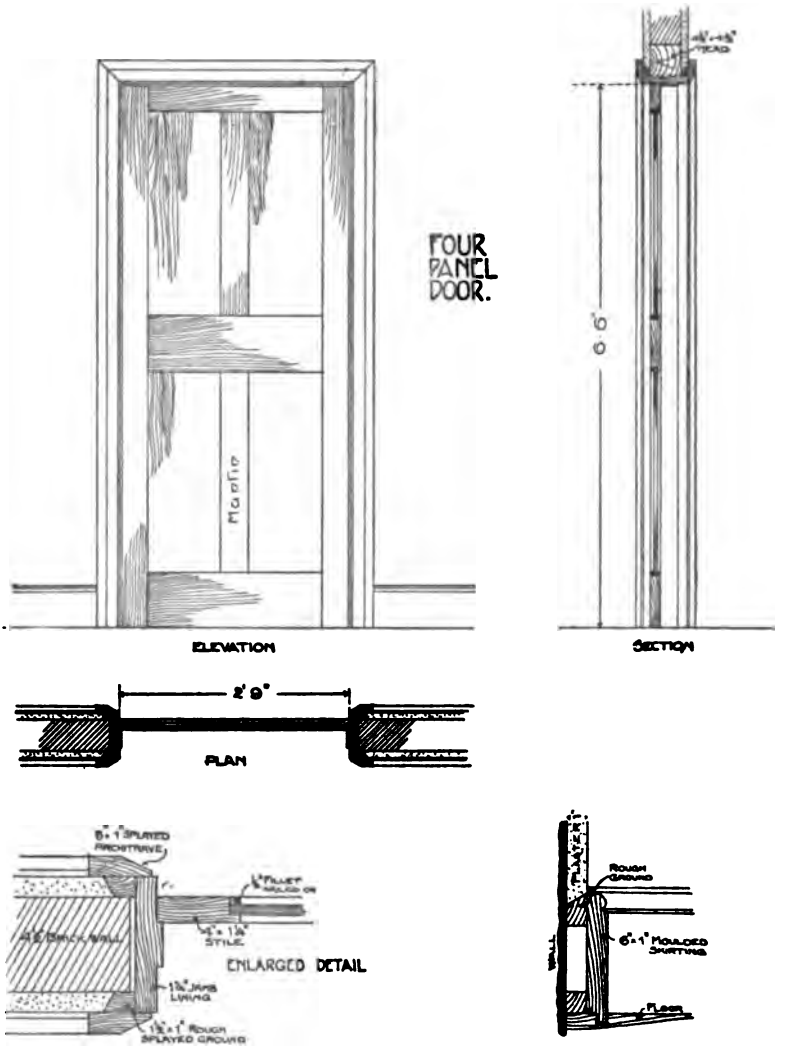


Fig. 193.

subsequent modifications of framed doors, are heavier than the two first named, it is advisable that the feet of the posts should be secured by iron dowels, which are round, pencil-shaped pieces of galvanised iron about 3 inches long and $\frac{3}{8}$ to $\frac{5}{8}$ inch in diameter, half their length being let into the feet of the posts and half into the

stone or wood upon which the posts rest. It is a simple matter to admit light through such a door by omitting part of the upper

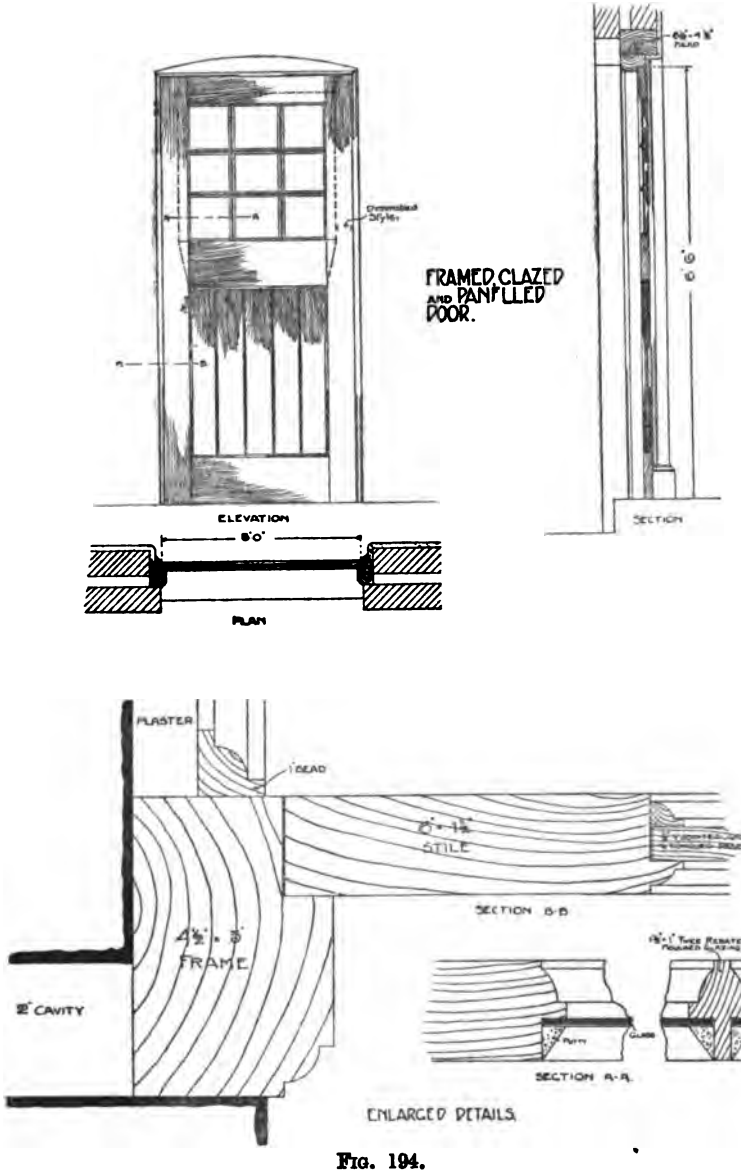


Fig. 194.

boarding and providing an extra rail, in which case the upper brace would require to be kept below the extra rail, and the rectangle or square thus formed between the top and extra rails is glazed in

the usual way. When it is desirable that such a door shall open and shut in the usual way its weight generally necessitates the use of hooks and bands in the place of cross garnet hinges. The hooks are either attached through screw holes in a back plate to the hanging post or are made with sharp tails which enable them to be driven in to the hanging post. The hooks are then bolted along their length to the top and bottom rails and are provided with ends which are forged to fit over the hooks. In farm buildings it is frequently more convenient that doors should open and shut by sliding backwards and forwards, and whether they be large or small doors of the framed and braced type, the most satisfactory method of arranging the sliding action is by fixing metal bands, of similar dimensions to those just mentioned, vertically to the door at the top of the hanging and meeting styles. The straps in this case are fitted above the head of the door with small grooved wheels which fit over and roll on an overhead rail, which is fixed to a piece of timber securely incorporated with the wall above. In order to keep the foot of the door to the line on which it is intended to run to and fro the underside of the bottom rail may either be grooved to fit over a projecting bead of metal set in concrete or fastened to a timber in the ground, or it may be found sufficient fix in the ground three or four projecting guides.

Framed and Panelled Doors belong chiefly to internal work, and are more highly finished and in some cases extremely ornamental, with moulding and artistic panelling. The braces are omitted, giving place to a central vertical member known as a 'muntin' which is placed between the top and middle, and the middle and bottom, rails. The most usual door of this type has four panels, but these may, of course, be as numerous as individual taste or particular conditions require. It will be seen that the rails and muntins are responsible for dividing the door up into rectangles, and it is these latter, which are panelled either with single thin sheets of wood or with panel boarding, or again with glass, where it is desirable that the door shall admit the light. The usual method of introducing the panels is by rebating the edges of the styles, rails, and muntins, and placing the panel therein, securing it with nails, screws, or glue, and covering the joint with a length of beading or moulding.

Sash Doors are principally used for entrances, and are glazed in the upper part. The styles, as shown in Fig. 194 are usually, diminished at the middle rail, and glazing bars can be framed in, if the design requires several small panes of glass.

Windows

This is a question to which due attention must be given, since not only is it one of hygienic importance, but also one of appearance. Particularly does this latter point affect the question when house-building is under contemplation. It is possible in the main to divide windows into two classes: (1) Casement; (2) Double-hung sashes. The first type can be looked upon as the

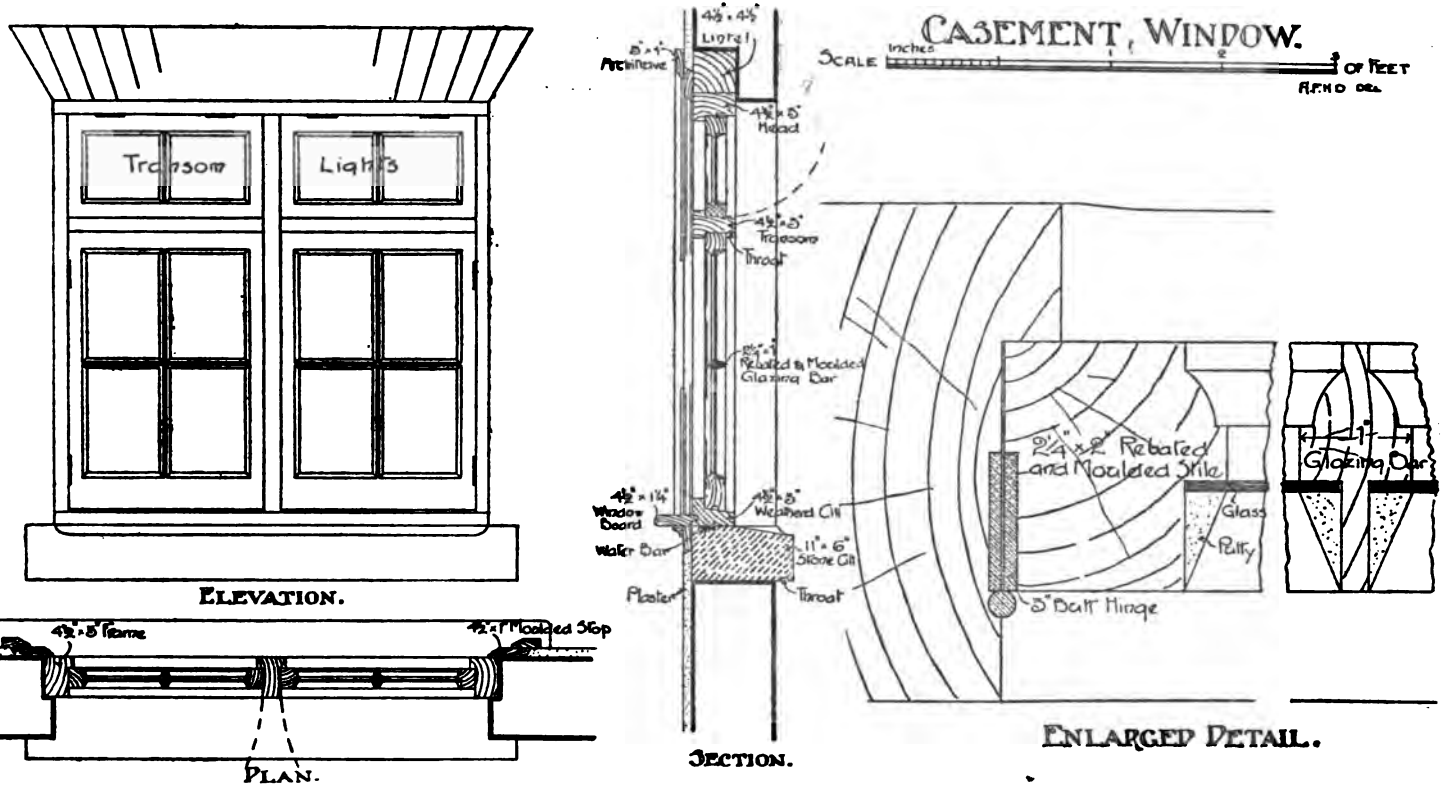

CASEMENT, WINDOW.
SCALE
Inches
OF FEET
Transom
Lights
ELEVATION.
4½" × 5" Frame
4½" × 1" Moulded Stop
PLAN.
4½" × 4½"
Lights
5" × 1"
Architrave
4½" × 5"
Head
4½" × 5"
Transom
Throat
5" × 1"
Rebated & Moulded
Glazing Bar
4½" × 1¼"
Window
Board
Water Bar
Plaster
4½" × 5"
Weathered Sill
11" × 6"
Stone Sill
Throat
SECTION.
2¼" × 2" Rebated
and Moulded Stile
Glass
Putty
5" Butt Hinge
1"
Glazing Bar
ENLARGED DETAIL.

FIG. 195.

most convenient, particularly because of the simplicity of construction, and therefore the lesser likelihood of the windows getting out

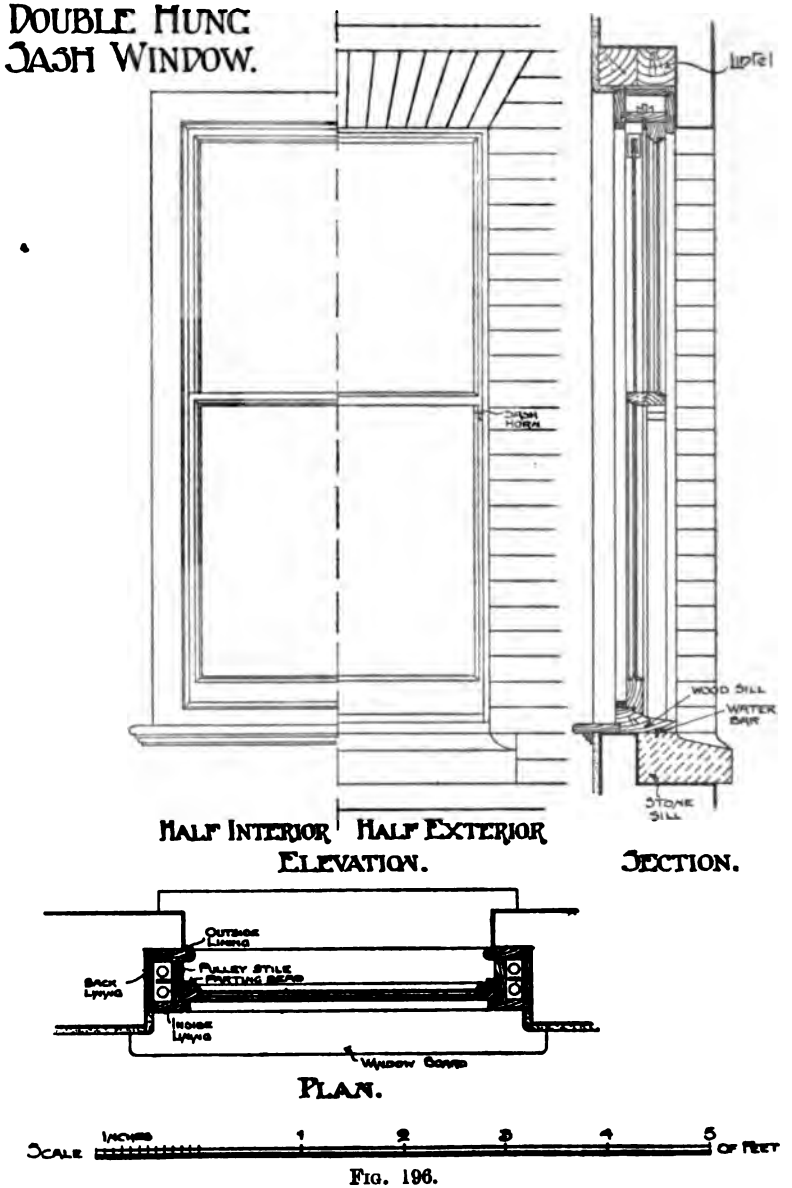


FIG. 196.

of order. It is, of course, not possible to make a sweeping assertion that any special type of window will in all cases be the best; for

individual taste has always to be reckoned with. The construction of the two types will be understood from the accompanying illustrations. As regards the casement windows, care should be taken to make them of convenient size to open and, wherever possible, provide upper or transom lights which are hinged at the top and open outwards. This precaution surmounts a very usual difficulty existing in the case of such windows during high winds and rain, since to open the windows at all, means that the aperture must exist throughout their height. The transom lights, however, are hung to open in such a way that ventilation is provided without causing considerable draught and admitting the wet. Whereas double-hung sashes are made of ranging sizes to suit requirements in different rooms and yet have the appearance of matching each other, casement windows should be made up of multiples of the same size light. For example, the size of a casement should be decided upon—say 3 feet high and 1 foot 9 inches wide. A water closet will require perhaps only one of these, but a sitting-room four or even five. It is merely a matter of increasing the total window space light by light, each unit of which is 3 feet by 1 foot 9 inches.

The glass chosen for windows will vary in thickness according to the size of the panes. The larger the latter are the heavier will it be necessary to specify the glass, and in large sheets the glass should be as thick as $\frac{1}{8}$ inch. The usual weights of glass sold and specified are 15 oz., 21 oz., 26 oz., and 32 oz. per square foot. Heavier glass than these weights are known as plate glass. Any of the various weights of glass can be procured in muffled or obscured variety, and are used in positions such as water closets, bath-room doors, &c., where it is desirable that light should be admitted, but that it should not be possible to see through. In better-class glazing, the glass should first be sprigged firmly in position by means of small metal tacks and then secured with putty.

It is frequently necessary to construct windows for rooms on upper floors which rise out of the roof slope, and are not placed in the main wall of the house. In this case the treatment of the rafters is very similar to that of the joists in a floor, where they are trimmed round a fireplace or staircase opening. That is to say, they are trimmed so that a recess may be formed giving sufficient headroom to approach the vertical space in which the window is fixed. The framing is built up round this vertical space and the window itself fixed very much in the usual way, and overhead, where the recess projects horizontally away from the slope of the roof, either a separate little gable or a flat zinc or lead roof is constructed.

In the case of what is known as a roof light or dead light such as is often constructed in the roof of a stock-house or loft, the rafters are trimmed out leaving a rectangular opening, which is first of all lined with boarding 1 to $1\frac{1}{2}$ inches thick, and the light fixed to the upper edges of the lining at a height somewhat above the level of the slates or tiles. The four sides of the lining above the roof

are then dressed with lead to make a watertight joint. The light may, of course, be fixed or made to open and shut from inside and hinged at the top. Roof lights are made with the lowest sheets of glass projecting slightly over the bottom rail of the frame, which is therefore made rather thinner than the sides and the top.

Louvres for ventilation, as may be seen in the drawings of the cowhouse, are simple in construction and may be made either in one continuous length or in separate and smaller lengths. Again, in this case the rafters require to be trimmed, and it is usually the trimmers on either side of the ridge level which act as bearers for

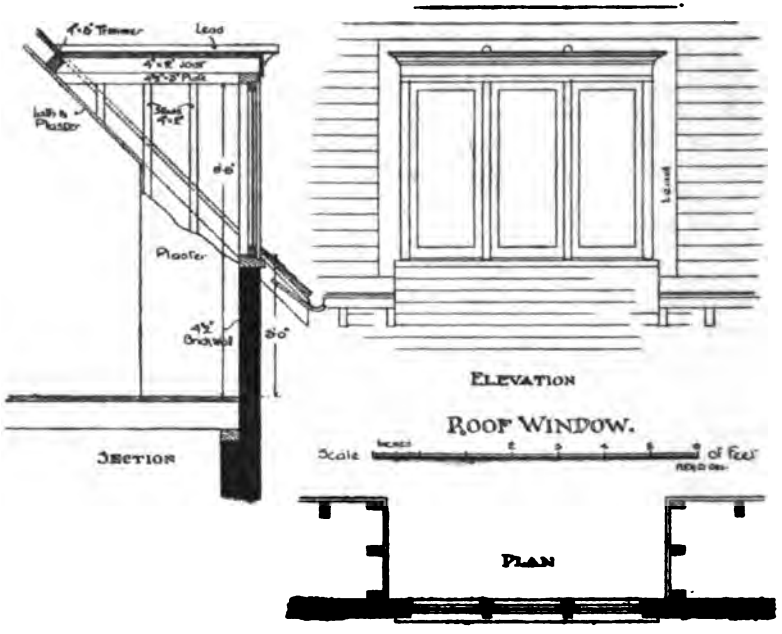


FIG. 197.

the uprights. A head runs along the tops of the uprights and forms a wall plate for the rafters of the small roof. The louvre boards themselves are fixed into grooves, cut at an angle in the sides of the upright posts (usually at about 45°), and are arranged on the system that the top of one is on a level with the bottom of the one above. Since the trimmers, which are also bearers, are acting as ridge boards to the rafters of the main roof, it is, of course, necessary to block them apart at intervals of about 4 feet. Vertical louvres may also be constructed in walls, in which case the frame is built into the wall in a similar way to that of a window and the louvre boards fixed as above.

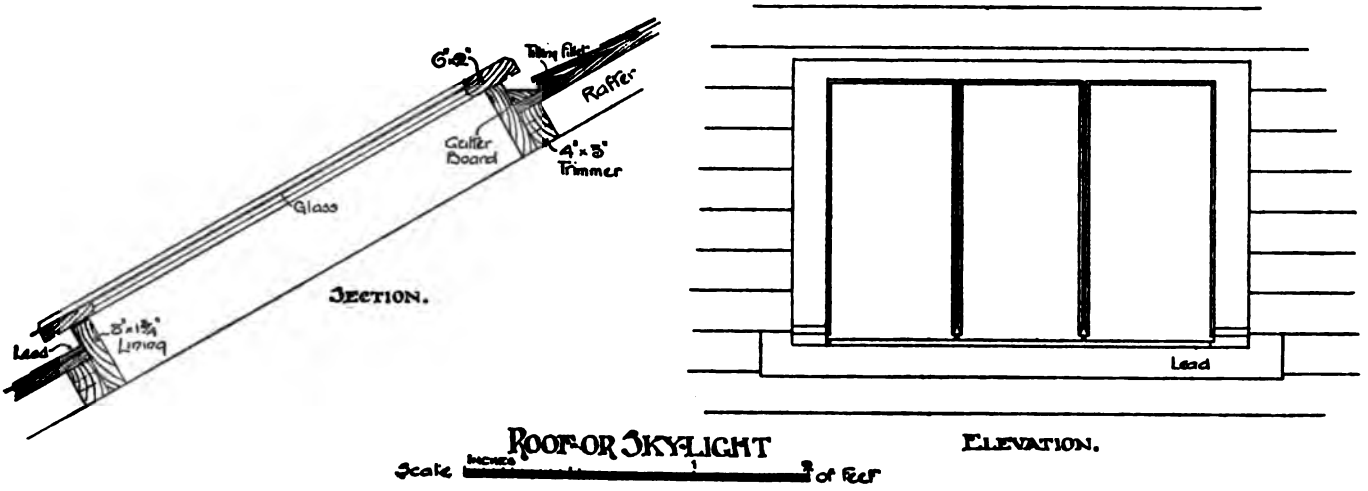

Rafter
Gutter Board
4"x3" Trimmer
Glass
Lead
3"x1¾" Lining
Section.
Lead
Elevation.
Roof or Skylight
Scale Inches 1 2 of Feet

Fig. 198.

Staircases

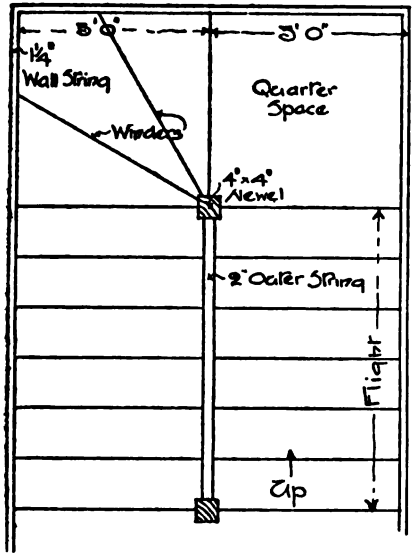
For the purposes of this work, dealing as it does with simple and straightforward questions on farms and estates, it is not necessary to carry the explanation of staircase construction farther than is sufficient to make clear two different ways of constructing the means of getting from one floor to another. One of these is the usual type, known as 'dog-legged,' found in small houses and cottages; the other of simple construction and specially adapted for use in such positions as North Range buildings and the like.

A dog-legged staircase is one which for part of its length rises in one direction, and for the rest returning parallel and in the opposite direction to the first part, leaving no space between those two parts. These two parts are called 'flights' and, as a rule, should not contain more than twelve steps. As will be seen from the diagrams, steps are frequently constructed at the turn of the staircase in order to reach the required height as quickly as possible. When not necessary for this purpose these 'winders,' as they are called, should be omitted and substituted under most ideal conditions by a flat area called a 'half space.' If this latter be divided into two parts by a step at right angles to the flights, those parts are called 'quarter spaces.' It frequently happens that the width of the chamber containing the staircase is wider by some feet than the two flights together. In this case the staircase is termed *Open Newel*. A point which has to be considered in the construction of stairs is the passage up and down, not only of furniture, but also of a coffin. Two persons should also be able to pass each other conveniently, and for these purposes it is wise never to build stairs less than 2 feet 9 inches in width. The pitch of stairs will naturally vary with the space at disposal, steepness increasing as the size of the houses decreases. The comparison of the breadth of the 'tread' (which is the part upon which the foot is placed) with the height of the 'riser' (i.e. the vertical distance between each step and the next) is given as follows:

Tread	Riser
7 inches	8 inches
8 ,,	7½ to 8 ,,
9 ,,	7 to 7½ ,,
10 ,,	6½ to 7 ,,
11 ,,	6 to 6½ ,,

Newels are the posts—either moulded or square—at the bottom, top, and turns of a staircase. Between and securely fixed to them runs the 'outer string' to which runs parallel the inner or 'wall string,' which is secured to the wall containing the staircase. These two strings form the support for the steps which are fitted into horizontal grooves and tightened by wedges. The risers are also provided with grooves in the strings, and are jointed with the treads above and below. Triangular blocks are glued at the back of the risers and the under side of the treads to keep them together, and the treads usually project by about 1 inch over the risers, giving a

STAIRS.



PLAN OF DOGLEGGED STAIRS

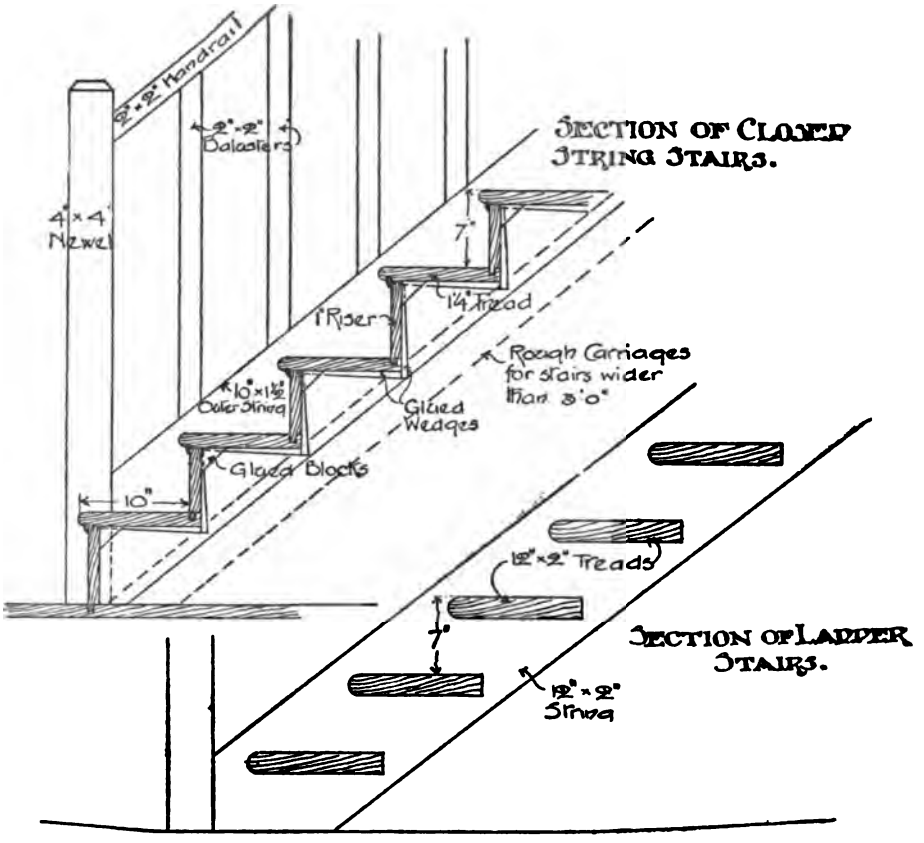


FIG. 199.

little extra space for the foot without taking up any more of the available length in which the stairs are to be contained. In some cases rough bearers are fixed from the top of each flight to the bottom to support the steps across their width. These are, of course, hidden from sight by the outer string. The handrail is fixed—at a convenient height from and parallel to the pitch of the stairs—to the newel posts on the outer side of the stairs, and the space between it and the top of the outer string provided with square or turned 'balusters' at small intervals. The under side of the stairs may either be lathed and plastered or boarded, or it may be enclosed to form a cupboard. This latter method is, perhaps, the most convenient and satisfactory in small houses and cottages, where space is limited and cupboards valuable.

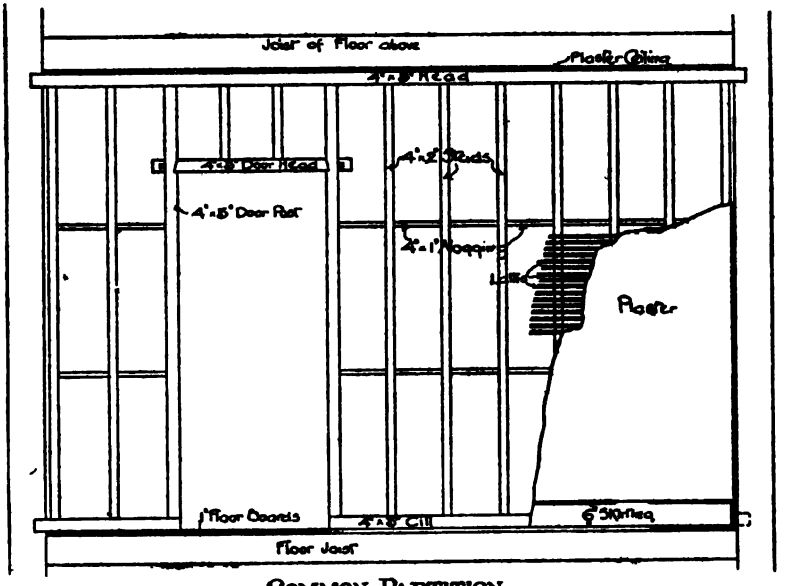
The type of stairs for a North Range is simpler than the above, as it need only consist of outer and inner or wall strings, treads, newels, and handrail. The treads are made from 1½ to 2 inches thick, with rounded noses and tenoned and housed into the strings. The absence of risers or any obstruction between each tread provides more room for the foot when mounting the stairs. Care should be taken to construct such stairs of ample width—3 feet as the minimum—and not too steep or narrow in the tread, as there will be considerable traffic up and down of labourers in heavy boots and frequently shoulder-laden. The extra outlay in the construction of a convenient and easy staircase may in all probability be a means of saving the expense of broken arms and legs—to say nothing of necks—belonging to careless employés.

Partitions

It is very often necessary to divide a space into two or more small rooms where either economy has to be studied or, in the case of an instance on an upper floor, when there is no wall directly below upon which to support the construction. In either case the substitution of timber in the form of framework surmounts the difficulty. As far as this book is concerned, the majority of cases will be adequately provided for, by a *Common Partition* which, as will be seen from the diagram is composed of a head and cill, vertical members called 'studs' which are stiffened by two or three rows of solid strutting called 'nogging pieces,' and an opening for a doorway. The whole framing is lathed over and plastered, producing a light serviceable wall of about 6 inches thick. Common partitions should be supported either at right angles to and upon the floor joists or centrally along one single joist. There is another method of supporting the partition when its position between the joists cannot be avoided; this is by placing bridging pieces between the two joists, and then supporting the cill of the partition at intervals along its length.

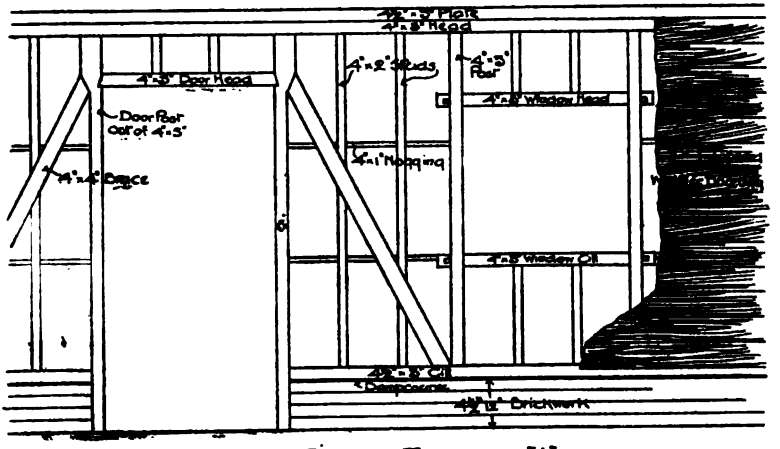
In contradistinction to the above type of partition which, as explained, derives its support from the floor upon which it rests, the *Trussed Partition* is self-supporting in that it is composed of a head and a cill, each of which is similar in function to the tie-beam

of a roof truss, i.e. they are built into the wall at each end and rest upon templates. The construction between the head and the cill



COMMON PARTITION.

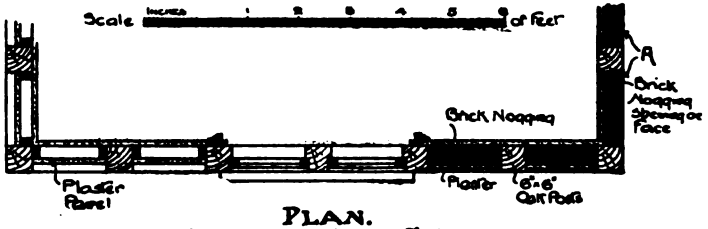
Scale 1 2 3 4 5 6 7 8 of Feet



FRAMED EXTERNAL WALL.

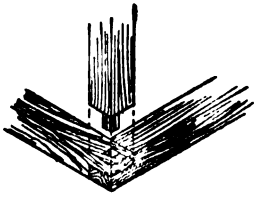
FIG. 200.

further resembles the king post or two queen posts of a roof truss, as will be seen from the diagram. Struts do not, however, occur as in a roof truss, being substituted by a series of studs as in the common partition, with nogging pieces to act as stiffeners.

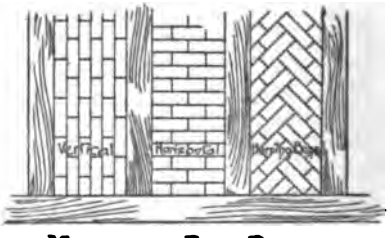


PLAN.

Showing Alternative Methods of Panelling.



Junction of Angle Post & Cill



METHODS OF BRICK PANELLING A & A.

FIG. 201.

Another method of building a partition which has no wall underneath to act as a support, but which, of course, does not rightly come under the heading of this chapter, is a simple construction of a rolled steel joist, supported at each end in the walls, and a 4½ inch brick wall built upon it.

The framing which is used for containing walls, as in small-holding farm buildings, upper floors of cottages, and other places where economy has to be studied, is very similar to the ordinary common partition, with the addition of extra strengthening braces which are introduced diagonally and pass through about four vertical studs each. In the case of an external timber-framed containing wall the laths and plaster are, of course, omitted in most cases, being substituted by vertical tiling or slating, weather boarding, &c. The surface can also be rough cast as before explained, in which case the battens are fixed as if for internal plastering.

Half-timbered work is similar in idea to that just described, except that the framing is stronger and of better class timber which shows in the face of the building and makes for artistic appearance. The spaces between the timbers may either be filled in with brickwork, tiles, or rough cast. The wood in half-timbered work should be of oak as it is exposed to the weather. Pine is sometimes used, but is not as satisfactory as oak.

Prices

	£	s.	d.
Roofs, including fir rafters, boarding, felt, slates or tiles, flashings, &c. . . . per square	5	10	0
Roof trusses, reckoned extra, the timber being cubed up and priced as before quoted.			
Doors (deal) complete with frames, furniture, and painting . . . . average per sq. foot	0	2	6
Windows, complete with frames, furniture, painting and glazing: Casements per sq. foot 2*s.* 6*d.* to	0	3	0
Double-hung Sashes per sq. foot	0	3	0
Roof lights (inclusive) . . per sq. foot 1*s.* 6*d.* to	0	2	0
Louvres (see Priced Bill of Quantities of Double Cow-house).			
Staircases. 3 feet wide . . per tread and riser	0	17	6
3 feet 6 inches wide ,, ,, ,, ,,	1	2	0
4 feet wide . ,, ,, ,, ,,	1	5	0
Common Partitions. Plaster both sides and paper per square	3	0	0
Trussed Partitions. (Add for trusses to above.)			
Half-timbered work. Cube up all timber and add for any brickwork, rough cast, &c.			

CHAPTER XVIII

HYGIENE

SUCH an important subject as hygiene can well be dealt with at great length and in a volume entirely to itself, as it includes such an infinite variety of departments, important points, and vital necessities. However, it is intended here to deal as briefly as possible with all such points as are of the greatest importance in farm buildings, which include the dwelling-house for the purpose of this chapter.

In order to provide, not only for the well-being and healthy condition of all stock, but also for the hygienic production of such an important product as milk, every point which makes for perfect sanitary conditions must be remembered and provided for. Ventilation is a question which will naturally assail the mind first of all, and there is no doubt that this is the point of premier importance. Both in stables and cowhouses—and, indeed, in all stock-houses which are closed at night—due provision must be made for the admission of fresh air. Inlets at the rate of one per head of cattle or horses and measuring 9 inches by 3 inches should be provided in the walls at a low level, some 6 inches or a foot above the ground level, and some form of outlet for vitiated air should be provided in the roof. A single cowhouse, loose boxes, stables of reasonable size, and the like can be adequately and inexpensively ventilated in this way by raising the alternate or every third ridge tile, and setting it upon those at each side, as shown in the drawing of the stable building; but in larger enclosed areas, such as double cowhouses and covered yards, it is more satisfactory to build a separate ventilator of the louvre variety at the top of the roof. This may either be continuous throughout the roof, as shown in the drawing of the double cowhouse, or formed in separate erections. Cubic air space again is an important point and there should be no doubt, when building a stock-house of any description that it will contain a capacity at the rate of 600 to 800 cubic feet per beast. The variance just given is applicable to cattle, as it is necessary to provide more air space in a cowhouse whose occupants spend their entire lives therein than in one which is used only for milking and at night. The dimensions of stalls need not be given here, as they are shown on the plans of the various buildings. In yards and

boxes the floor area should admit of there being about 150 square feet per head, in order to obviate overcrowding. Light is almost as important as any other factor and without it no stock-house can be said to be in a thoroughly sanitary and hygienic condition. It may be provided in a variety of ways: (1) By windows in the walls; (2) By roof lights or skylights, which may or may not be made to open; (3) By glass tiles, which is an inexpensive and quite satisfactory method; (4) By glazing the roofs of louvre ventilators—this is also a fairly inexpensive means of obtaining light. In the majority of cases surrounding buildings and adjacent covered yards make windows in the walls an impossibility—at any rate for the purpose required—which leaves the choice between the methods of lighting in the roof. But in any case the provision should be at the rate of 2 square feet of glass per head of live stock.

We next come to the question of drainage, and there is no doubt that the most perfect system of conducting liquid manure out of stock-houses is by means of open-drain channels whose inclination is made sufficient to cause a reasonably quick flow. The dimensions of those in stock-houses, stables, &c., will be found on the various drawings. In the case of covered yards where there is no possibility of the rain washing the richness out of the accumulated litter, straw and dung, no drain will be required, as the manure is from time to time removed and used on the land in all its valuable richness. But from those points in the farm buildings where liquid manure has been conducted out of stock-houses, &c., 4-inch drain pipes should be laid with a fall of 1 in 40, leading either to a main system of drainage or to a liquid manure tank, whose contents will ultimately be used on the land. It is important in the laying of all drain pipes that the vertical and horizontal line should be kept perfectly true and straight and where any bend or fall occurs an inspection chamber should be provided (Fig. 202, p. 256). It is preferable to lay all drain pipes in concrete, but in any case the greatest care must be observed in jointing and what is known as 'alignment'—i.e. the bore of one length coinciding with that of the next, so that there is no ridge caused by eccentric laying. Gulley traps are usually provided at the inlet to any drain pipe, and are so constructed that there is always a liquid seal, which prevents the stench from re-entering the place whence the liquid manure originates. Intercepting traps, of a similar construction as regards the prevention of the return of gases, should be provided at any points where small branches join main drains or sewage tanks, and it is always necessary to ventilate any reasonable length of drain by providing fresh air inlets and foul air outlets. The former are fitted with a flap usually made of mica which, since it only opens inwards, prevents any action but the inlet of fresh air. The foul air outlets are merely pipes, which should be attached to any near vertical surface such as trees or buildings and taken up to a sufficient height to insure the escape of the foul air into the upper atmosphere well above any neighbouring building. A type of useful liquid manure tank is

shown in Fig. 204, and the size of such will naturally vary with the capacity required.

Speaking generally, the most desirable conditions will be bound

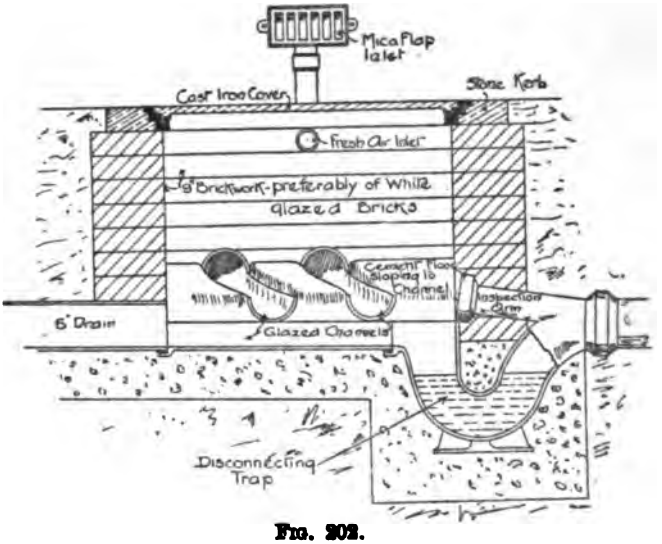


FIG. 202.

to exist in all stock-houses if the byelaws which are made to govern those farms where milk is sold are faithfully observed in all cases, whether the milk be sold or not. A copy of those Regulations is set out hereafter, and will naturally vary, though very slightly, under various local authorities. The same may be said of the bye-laws in connection with dwelling houses and domestic buildings, and though it is happily not necessary to enforce such rigid rules in rural as in urban districts, it is nevertheless year by year making for the decrease of disease and better condition of the poor and labouring classes that such can only be built subject to the approval of sanitary authorities in every district.

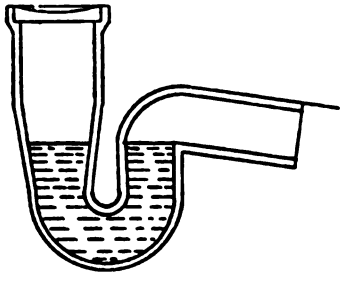


FIG. 203.—GULLEY TRAP.

Very much the same points are of importance when considering dwelling houses as are patent in all hygienic provisions for stock-houses. That is to say, adequate ventilation, light, cubic air space and floor area are each of great necessity, and though frequently the amount provided in each case is well in excess of the require-

ments of the byelaws, those laws form a very helpful basis upon which to go to work in building labourers' cottages, &c. Unfortunately it is a fact that in several cases where such buildings are adequately furnished with sanitary and hygienic contrivances, the effect of the latter is nullified by the occupants. Ventilators are stopped up, flues blocked with sacks filled with shavings, windows kept shut, baths used for seed potatoes, and such like outrages against perfect sanitation and cleanliness. However, these foibles of the class in question are unlikely to be cured, and one can but at any rate make all due and timely provision. whether the occupants

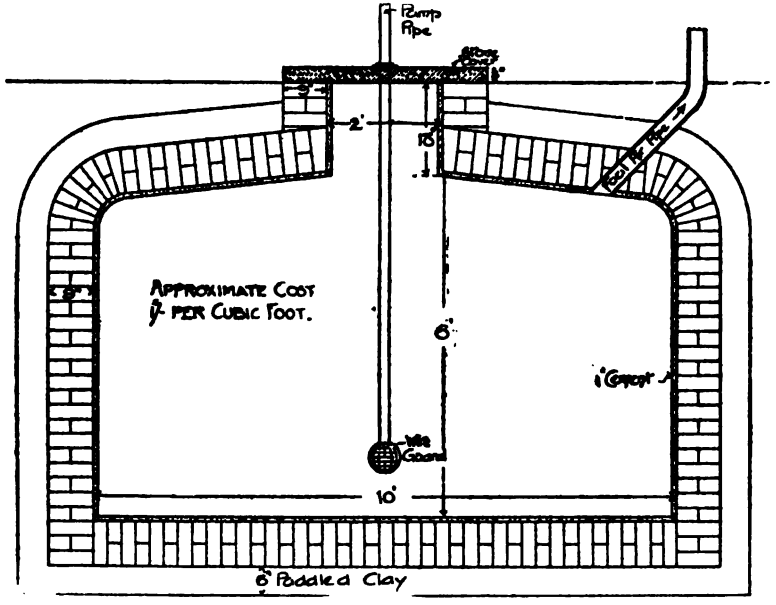


Fig. 204.

choose to benefit therefrom, and thus better their condition, or whether they revert to type. It is only possible to be sure that children and animals will derive the benefit accruing as a result of byelaws framed for their good, and that the elders and 'betters' will do likewise can but be a vague and constant hope.

Prices

	£	s.	d.
Air inlets in walls, 9″ × 3″ . . . 9d. to	0	1	0
Drain-laying (inclusive) . . . per foot run	0	1	9
Bends . . . . 3″, 6d.; 4″, 1s. 3d.; 6″	0	1	6
Junctions—Single . . 3″, 1s.; 4″, 1s. 9d.; 6″	0	2	6
,, Double . . 3″, 1s. 6d.; 4″, 2s.; 6″	0	3	0

	£	s.	d.
Inspection chambers (according to size and depth) £3 to	10	0	0
Disconnecting traps, brown ware . 4″, 8s.; 6″	0	10	6
Gullies . . . . . 4″ and 3″ outlet	0	5	6
,, ... 6″ and 4″ ,,	0	8	0
,, ... 9″ and 4″ ,,	0	10	6
Manure tanks . . . . . per cubic foot	0	1	0
Glass tiles ¼″ thick 13″ × 7″, each 6d.; 16″ × 8″, each	0	0	8
20″ × 10″, each 11d.; 24″ × 12″, ,,	0	1	3
Air inlets to drains . . . . . ,,	0	8	0
Roof lights . . . per foot super. 1½″, 10d.; 2″	0	1	0

MODEL REGULATIONS ISSUED BY THE LOCAL GOVERNMENT BOARD

XIX.—Dairies, Cowsheds, and Milk-shops *

Memorandum

Article 13 of the Dairies, Cowsheds, and Milk-shops Order of 1885, issued by the Privy Council in pursuance of Section 34 of the Contagious Diseases (Animals) Act, 1878 (41 and 42 Vict., c. 74), provides that 'a Local Authority may from time to time make regulations for the following purposes, or any of them :—

'(*a*) For the inspection of cattle in dairies.

'(*b*) For prescribing and regulating the lighting, ventilation, cleansing, drainage and water-supply of dairies and cowsheds in the occupation of persons following the trade of cowkeepers or dairymen.

'(*c*) For securing the cleanliness of milk-stores, milk-shops, and of milk-vessels used for containing milk for sale by such persons.

'(*d*) For prescribing precautions to be taken by purveyors of milk and persons selling milk by retail against infection or contamination.'

The following provisions apply to any regulations so made :—

'(1.) Every regulation shall be published by advertisement in a newspaper circulating in the District of the Local Authority.

'(2.) The Local Authority shall send to the Privy Council [now Local Government Board] a copy of every regulation made by them not less than one month before the date named in such regulation for the same to come into force.

'(3.) If at any time [the Local Government] Board are satisfied on enquiry, with respect to any regulation, that the same is of too restrictive a character, or otherwise objectionable, and direct the revocation thereof, the same shall not come into operation, or shall thereupon cease to operate, as the case may be.'

(*See* Article 14 of the Order.)

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The expression 'Local Authority' means (outside the Metropolis) the Council of any Urban or Rural District, and includes the Council of a County Borough.

By the operation of Section 9 (1) of the Contagious Diseases (Animals) Act, 1886 (49 and 50 Vict., c. 32), the jurisdiction of the Privy Council under Section 34 of the Contagious Diseases (Animals) Act, 1878, and the Dairies, Cowsheds, and Milk-shops Order of 1885, has been transferred to the Local Government Board.

After consideration of the Report of the Royal Commission on Tuberculosis,[1] a model series of regulations has been prepared by the Board for the guidance of Councils in making regulations under the Order.

The model has been framed with close regard to the terms of Article 13 of the Order, which determines the matters that can be dealt with by regulation. Under other Articles of the Order local authorities have large powers of control over persons following or proposing to follow the trade of cowkeeper, dairyman or purveyor of milk, but in framing regulations the Board consider that the precise terms and limitations of Article 13 must be borne in mind.

It will be seen that No. 8 of the Model Regulations, which deals with the question of air space in cowsheds, does not apply to cowsheds the cows from which are habitually grazed on grass land during the greater part of the year, and, when not so grazed, are habitually turned out during a portion of each day; and it is obvious that a regulation on this subject, which might be adapted to cowsheds in towns, where the cows are kept and fed within the building, might be unsuitable for cowsheds in the country where the cows are regularly grazed on grass land during the greater part of the year, and are during the rest of the year usually turned out for a portion of each day.

The Royal Commission, in their recommendations, drew a distinction between the rules which should be observed on this subject as regards cowsheds situate in populous and those situate in non-populous places, but no indication was given as to the means by which this distinction was to be made. The clauses suggested by the Board, however, seek to give effect to the recommendations of the Commissioners by recognising that which probably constitutes the chief difference between cowsheds in town and cowsheds in the country, viz.: that in the one case cows are kept entirely, or as a rule, indoors, and that in the other cows are usually turned out to graze, and by distinguishing between the two classes of cases.

It will be noticed that No. 4 of the Model Regulations which provides that every cow-keeper must cause every cowshed in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the cowshed in a wholesome condition, applies in both classes of cases.

[1] Parliamentary Paper (C. 8824), 1898.

For the purpose of enforcing any Orders made under Section 34 of the Contagious Diseases (Animals) Act, 1878, and any Regulations made thereunder, Section 9 (4) of the Contagious Diseases (Animals) Act, 1886, provides that :—

'The Local Authority and their officers, for the purpose of enforcing the said Orders and any regulations made thereunder, shall have the same right to be admitted to any premises as the Local Authority, within the meaning of the Public Health Act, 1875, and their Officers have, under Section 102 of that Act, for the purpose of examining as to the existence of any nuisance thereon ; and if such admission is refused the like proceedings may be taken, with the like incidents and consequences as to orders for admission, penalties, costs, expenses, and otherwise, as in the case of a refusal to admit to premises for any of the purposes of the said Section one hundred and two, . . .

'Provided that nothing in this section shall authorise any person, except with the permission of the Local Authority . . . to enter any cowshed or other place in which an animal affected with any disease is kept, and which is situate in a place declared to be infected with such disease.'

The terms of Section 102 of the Public Health Act, 1875 (38 and 39 Vict., c. 55), are as follows :—

'The Local Authority, or any of their officers, shall be admitted into any premises for the purpose of examining as to the existence of any nuisance thereon, . . . at any time between the hours of nine in the forenoon and six in the afternoon ; or in the case of a nuisance arising in respect of any business, then at any hour when such business is in progress or is usually carried on.

. . . . . .

'If admission to premises for any of the purposes of this section is refused, any justice on complaint thereof on oath by any officer of the Local Authority (made after reasonable notice in writing of the intention to make the same has been given to the person having custody of the premises) may, by order under his hand, require the person having custody of the premises to admit the Local Authority, or their officer, into the premises during the hours aforesaid, and if no person having custody of the premises can be found, the justice shall, on oath made before him of that fact, by order under his hand authorise the Local Authority or any of their officers to enter such premises during the hours aforesaid.'

. . . . . .

As to the consequences of disobedience to an order of justices for admission of the Local Authority or any of their officers, and the costs and expenses connected with the order, attention may be directed to Sections 103 and 104 of the Act of 1875.

With regard to penalties for offences against the Regulations, Section 9 (5) of the Contagious Diseases (Animals) Act, 1886, provides that :—

'The like penalties for offences against . . . regulations made for the purposes of Section 34 of the [Contagious Diseases (Animals) Act, 1878], as amended by this section, may be imposed by the . . . Local Authority making the same, and such offences may be prosecuted and penalties recovered in a summary manner, and subject to the like provisions, as if such . . . regulations were bye-laws of a Local Authority under the Public Health Act, 1875, . . .'

In connection with this enactment, reference may be made to Sections 183 and 251 to 254 (both inclusive) of the Act of 1875.

The Board's confirmation of any regulations which may be made by the Council will not be required, but if at any time the Board are satisfied on enquiry with respect to any regulation that the same is of too restrictive a character, or otherwise objectionable, they may direct its revocation (*see* Article 14 (3) of the Order of 1885); and the Board suggest that the draft of any regulations which the Council may propose to make should be sent to them for consideration before the regulations are formally adopted. Forms for this purpose with wide margin will be supplied by the Board on application.

S. B. PROVIS,
Secretary.

Local Government Board,
10th June, 1899.

NOTE.—*It is suggested that any Local Authority proposing to make regulations on this subject should apply to the Local Government Board for draft forms on which to submit the regulations for the consideration of the Board, before they are adopted by the Local Authority.*

REGULATIONS made by the[1]

WITH RESPECT TO DAIRIES, COWSHEDS, AND MILK-SHOPS IN THE[2]

Interpretation.

1. Throughout these regulations the expression 'The Council' means the[1] , acting by the Council'; *or* 'Urban (*or* Rural) District Council of ';

the expression 'the District' means the[2] ,' *as the case may be.*

[1] 'Mayor, Aldermen, and Burgesses of the Borough of *as the case may be.*

[2] 'Borough,' *or* 'Urban (*or* Rural) District of *may be.*

the expression 'Cowshed' includes any dairy in which milking cows may be kept, and the expression 'Cowkeeper' means any person following the trade of a cowkeeper or dairyman who is, or is required to be, registered under the Dairies, Cowsheds, and Milk-shops Order of 1885.

For the inspection of Cattle in Dairies.

2. Every occupier of a dairy wherein any cattle may be kept, and which the Medical Officer of Health, or the Inspector of Nuisances, or any other officer of the Council specially authorised by them in that behalf, may visit for the purpose of inspecting cattle, and every person for the time being having the care or control of any such dairy, or of any cattle therein, shall afford such Medical Officer of Health, Inspector of Nuisances, or officer, all reasonable assistance that may, for the purpose of the inspection, be required by him.

For prescribing and regulating the lighting, ventilation, cleansing, drainage, and water supply of cowsheds and dairies in the occupation of Persons following the trade of Cowkeepers or Dairymen.

PART I.

The Regulations in this Part shall apply to Cowsheds the cows from which are habitually grazed on grass land during the greater part of the year, and, when not so grazed, are habitually turned out during a portion of each day.

Lighting.

3. Every cowkeeper shall provide that every cowshed in his occupation shall be sufficiently lighted with windows, whether in the sides or roof thereof.

Ventilation.

4. Every cowkeeper shall cause every cowshed in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the cowshed in a wholesome condition.

Cleansing.

5. (1.) Every cowkeeper shall cause every part of the interior of every cowshed in his occupation to be thoroughly cleansed from time to time as often as may be necessary to secure that such cowshed shall be at all times reasonably clean and sweet.

(2.) Such person shall cause the ceiling or interior of the roof, and the walls of every cowshed in his occupation to be properly limewashed *twice* at least in every year, that is to say, *once* during the month of May and *once* during the month of October, and at such other times as may be necessary.

Provided that this requirement shall not apply to any part of such ceiling, roof or walls, that may be properly painted, or varnished, or constructed of or covered with any material such as to render the limewashing unsuitable or inexpedient, and that may be otherwise properly cleansed.

(3.) He shall cause the floor of every such cowshed to be thoroughly swept, and all dung and other offensive matter to be removed from such cowshed as often as may be necessary, and not less than *once* in every day.

Drainage.

6. (1.) Every cowkeeper shall cause the drainage of every cowshed in his occupation to be so arranged that all liquid matter which may fall or be cast upon the floor may be conveyed by a suitable open channel to a drain inlet situate in the open air at a proper distance from any door or window of such cowshed, or to some other suitable place of disposal which is so situate.

(2.) He shall not cause or suffer any inlet to any drain of such cowshed to be within such cowshed.

Water Supply.

7. (1.) Every cowkeeper shall keep in, or in connection with, every cowshed in his occupation a supply of water suitable and sufficient for all such purposes as may from time to time be reasonably necessary.

(2.) He shall cause any receptacle which may be provided for such water to be emptied and thoroughly cleansed from time to time as often as may be necessary to prevent the pollution of any water that may be stored therein, and where such receptacle is used for the storage only of water he shall cause it to be properly covered and ventilated, and so placed as to be at all times readily accessible.

Part II.

The regulations in Part I., and also the following regulation, shall apply to all Cowsheds other than those the cows from which are habitually grazed on grass land during the greater part of the year, and, when not so grazed, are habitually turned out during a portion of each day.

8. A cowkeeper shall not cause or allow any cowshed in his occupation to be occupied by a larger number of cows than will leave not less than *eight hundred feet* of air space for each cow.

Provided as follows :—

(*a.*) In calculating the air space for the purposes of this regulation, no space shall be reckoned which is more than *sixteen feet* above the floor; but if the roof or ceiling is inclined, then the mean height of the same above the floor may be taken as the height thereof for the purposes of this regulation.

(*b.*) This regulation shall not apply to any cowshed constructed and used before the date of these regulations coming into effect, until two years after that date.

Part III.

9. In this Part, the expression 'Dairy' means a dairy in which cattle are not kept.

Lighting.

10. Every cowkeeper shall provide that every dairy in his occupation shall be sufficiently lighted with windows, whether in the sides or roof thereof.

Ventilation.

11. Every cowkeeper shall cause every dairy in his occupation to be sufficiently ventilated, and for this purpose to be provided with a sufficient number of openings into the external air to keep the air in the dairy in a wholesome condition.

Cleansing.

12. (1.) Every cowkeeper shall cause every part of the interior of every dairy in his occupation to be thoroughly cleansed from time to time as often as may be necessary to secure that such dairy shall be at all times reasonably clean and sweet.

(2.) He shall cause the floor of every such dairy to be thoroughly cleansed with water at least *once* in every day.

Drainage.

13. (1.) Every cowkeeper shall cause the drainage of every dairy in his occupation to be so arranged that all liquid matter which may fall or be cast upon the floor may be conveyed by a suitable open channel to the outside of such dairy, and may there be received in a suitable gulley communicating with a proper and sufficient drain.

(2.) He shall not cause or suffer any inlet to any drain of such dairy to be within such dairy.

Water Supply.

14. (1.) Every cowkeeper shall cause every dairy in his occupation to be provided with an adequate supply of good and wholesome water for the cleansing of such dairy and of any vessels that may

be used therein for containing milk, and for all other reasonable and necessary purposes in connection with the use thereof.

(2.) He shall cause every cistern or other receptacle in which any such water may be stored to be properly covered and ventilated, and so placed as to be at all times readily accessible.

(3.) He shall cause every such cistern or receptacle to be emptied and thoroughly cleansed from time to time as often as may be necessary to prevent the pollution of any water that may be stored therein.

For Securing the Cleanliness of Milk-Stores, Milk-Shops, and of Milk-Vessels used for containing Milk for Sale by Persons following the trade of Cowkeepers or Dairymen.

Cleanliness of Milk-Stores and Milk-Shops.

15. Every occupier of a milk-store or milk-shop shall cause every part of the interior of such milk-store or milk-shop to be thoroughly cleansed from time to time as often as may be necessary to maintain such milk-store or milk-shop in a thorough state of cleanliness.

Cleanliness of Milk-Vessels.

16. (1.) Every cowkeeper shall from time to time as often as may be necessary cause every milk-vessel that may be used by him for containing milk for sale to be thoroughly cleansed with steam or clean boiling water, and shall otherwise take all proper precautions for the maintenance of such milk-vessel in a constant state of cleanliness.

(2.) He shall, on every occasion when any such vessel shall have been used to contain milk, or shall have been returned to him after having been out of his possession, cause such vessel to be forthwith so cleansed.

For prescribing precautions to be taken by Purveyors of milk and Persons selling milk by retail against infection or contamination.

17. (1.) Every purveyor of milk or person selling milk by retail shall take all reasonable and proper precautions, in and in connection with the storage and distribution of the milk, and otherwise, to prevent the exposure of the milk to any infection or contamination.

(2.) He shall not deposit or keep any milk intended for sale—

(*a.*) in any room or place where it would be liable to become infected or contaminated by impure air, or by any offensive, noxious, or deleterious gas or substance, or by any noxious or injurious emanation, exhalation, or effluvium; or

(*b.*) in any room used as a kitchen or as a living room; or

(*c.*) in any room or building, or part of a building communicating directly by door, window, or otherwise with any room used as a sleeping room, or in which there may be any person

suffering from any infectious or contagious disease, or which may have been used by any person suffering from any such disease and may not have been properly disinfected; or

(*d.*) in any room or building or part of a building in which there may be any direct inlet to any drain.

(3.) He shall not keep milk for sale, or cause or suffer any such milk to be placed, in any vessel, receptacle or utensil which is not thoroughly clean.

(4.) He shall cause every vessel, receptacle or utensil used by him for containing milk for sale to be thoroughly cleansed with steam or clean boiling water after it shall have been used, and to be maintained in a constant state of cleanliness.

(5.) He shall not cause or suffer any cow belonging to him or under his care or control to be milked for the purpose of obtaining milk for sale—

(*a.*) unless, at the time of milking the udder and teats of such cow are thoroughly clean; and

(*b.*) unless the hands of the person milking such cow, also, are thoroughly clean and free from all infection and contamination.

Penalties.

18. Every person who shall offend against any of the foregoing regulations shall be liable for every such offence to a penalty of *five pounds*, and in the case of a continuing offence to a further penalty of *forty shillings* for each day after written notice of the offence from the Council.

Provided, nevertheless, that the justices or court before whom any complaint may be made or any proceedings may be taken in respect of any such offence may, if they think fit, adjudge the payment as a penalty of any sum less than the full amount of the penalty imposed by this regulation.

Commencement of the Regulations.[1]

19. These regulations shall come into force on and after the day of 19 .

Revocation of Regulations.[2]

20. From and after the date on which these regulations shall come into force, all regulations heretofore made under, or having effect in pursuance of the Dairies, Cowsheds and Milk-shops Order of 1885, shall, so far as the same are now in force in the district, be revoked.

[1] The date to be inserted in this clause should be one which will admit o compliance with the requirements of Article 14 (2) of the Dairies, Cowsheds, and Milk-shops Order of 1885.

[2] If this clause is not included in the series submitted to the Local Government Board for approval, it should be stated whether or not there are any regulations in force upon the subject.

MODEL BYELAWS ISSUED BY THE LOCAL GOVERNMENT BOARD

IV.—(RURAL DISTRICTS) *

Memorandum.

MODEL BYELAWS AS TO NEW BUILDINGS AND CERTAIN MATTERS IN CONNECTION WITH BUILDINGS IN RURAL DISTRICTS.

1. The authority to make byelaws for regulating new streets and buildings and matters connected therewith is conferred on Urban District Councils by section 157 of the Public Health Act, 1875, and section 23 of the Public Health Acts Amendment Act, 1890.

2. Rural District Councils are not directly authorised to make such byelaws, but can obtain power to make some or all of them in the following ways :—

(i.) A Rural District Council can, by adopting Part III. of the Act of 1890, acquire power to make byelaws upon the subject-matters referred to in paragraph 3 below ; or

(ii.) A Rural District Council may make application to the Local Government Board to be invested with such of the powers conferred by the sections as they deem suitable to their district, or to any one or more contributory places within it. Such an application can be made whether the Council have adopted Part III. of the Act of 1890 or not. The mode of making such an application is dealt with in paragraph 7 below.

3. The powers obtained under section 23 of the Act of 1890 where Part III. has been adopted, or where the provisions of that section have been put in force by an Order of the Board, enable a Rural District Council to make byelaws on the following subjects :—

(1) The structure of walls and foundations of new buildings for purposes of health ;

(2) The sufficiency of space about buildings to secure a free circulation of air ;

(3) The ventilation of buildings ;

(4) The drainage of buildings ;

(5) Waterclosets, earthclosets, privies, ashpits, and cesspools in connection with buildings ;

(6) The closing of buildings unfit for human habitation ;

(7) The structure of floors ;

(8) The height of rooms to be used for human habitation ;

(9) The keeping of waterclosets supplied with sufficient water for flushing ;

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(10) The alteration of buildings;
(11) The observance and enforcement of such byelaws by requiring notices and plans.

4. It has been represented to the Board that it would be useful if a series of model byelaws were framed, dealing only with the subjects which are most in need of regulation and control in a rural district from a sanitary point of view, and omitting the additional requirements usually found in a code of byelaws in force in an urban district. The Board have, therefore, drawn up the accompanying series of model byelaws. They are confined to matters affecting health, and are limited to the subject-matters numbered (1) to (6), (9) and (11) in paragraph 3 above.

The Board are not in a position to advise as to what byelaws are needed in particular rural districts. The responsibility rests with the Rural District Council in each instance of determining, on consideration of the circumstances of their district, what byelaws (if any) they will propose to make. The model is intended to serve as a guide to them in dealing with the most important sanitary requirements in connection with new buildings. It must not be regarded as excluding the adoption of further provisions, where these are found to be necessary, dealing with the other matters mentioned in section 23 of the Act of 1890, or in section 157 of the Act of 1875. Portions of many rural districts are distinctly urban in character, and the development of building is constantly changing the aspect of the country, and it devolves on Rural District Councils to endeavour to apply to the several parts of their districts such regulations as the circumstances may, from time to time, seem to require. The present series contains no clauses dealing with questions of stability or the prevention of fire, or with the level, width, and construction of new streets. These are all matters that may properly be regulated in portions of rural districts which are assuming an urban character, and circumstances may arise which may render it necessary to deal with one or more of them even in less closely populated areas. Where more comprehensive byelaws are considered to be necessary for the whole or any part of the district, the Rural District Council may be referred to the model series prepared for use in urban districts. They should carefully study the clauses and select those that are appropriate to the needs of the district, or the portion of it under consideration. In this connection it may be mentioned that a series of byelaws may be made for part only of a contributory place where the circumstances justify this course. The part should, however, be very clearly defined by a well recognised boundary line.

5. The following notes indicate the subject-matter of the several clauses included in the model series:—

Byelaw 1 defines certain terms used in the byelaws.

Byelaw 2 provides for the exemption of certain buildings from the byelaws. Special attention may be directed to the sub-division (*h*), the effect of which is practically to exclude from the operation

of the byelaws all buildings which are not dwelling-houses, or used wholly or partly for human habitation, or as a place for the habitual employment of any person. Thus the erection of buildings for agricultural purposes, and outbuildings such as a plant house, orchard house, summer house, poultry house, tool house, &c., is wholly unrestricted, except that they should not encroach on the open space required to be provided for new domestic buildings under the byelaws numbered 6 and 7. Pigsties and cowsheds are not exempt if not detached from a dwelling house. The object of this is to discourage the placing of such structures in contact with a dwelling house, as in such a position they must be regarded as a danger to health.

Public buildings and warehouse buildings are not excluded, but there are very limited provisions in the model byelaws respecting such buildings.

Walls and Foundations of New Buildings.

Byelaw 3 is for the purpose of securing the dryness of the ground surface beneath the building, and preventing the entrance of damp exhalations or of impure ground air from made ground or soil charged with organic matter. It only applies where the dampness of the site or the nature of the soil renders such a precaution necessary; but in low-lying marshy districts it may be desirable to omit the limiting words. It is suggested that a clause similar to clause 9 [1] in the existing urban model, prohibiting the erecting of buildings on ground filled up with offensive matter, should be adopted in districts where section 25 of the Public Health Acts Amendment Act, 1890, is not in force.

Byelaw 4 requires a damp course in every wall of a new public building, or of a building constructed for human habitation, and also requires a double wall to act as a vertical damp course where any part of the lowest storey of a building is below the surface of the ground.

Byelaw 5 is intended to secure the exclusion of damp from a building by water soaking into the walls through parapets.

Byelaws 4 and 5 are the only clauses proposed affecting the walls of buildings. In other respects as to size, material, position, strength, &c., the builder is entirely unfettered.

Space about Buildings to secure a free circulation of air.

Byelaws 6 and 7 deal with the provision of proper space to secure a free circulation of air. The Board regard it as most important that there should be secured for each new house, both in front and at the back, an adequate amount of space for this purpose. The open space in front required by byelaw 6 may extend over the public highway, and the clause is framed to meet the case of houses being erected fronting to existing narrow roads. It provides in effect that where a house is erected fronting to an existing street

[1] Clause 10 in later edition (1904) of urban model.

less than 24 feet in width, it shall stand at a distance of not less than 12 feet from the centre line of the street, thus effecting an equitable adjustment between the owners of sites on the opposite sides of the street.

Byelaw 7 requires the provision at the rear of the house of an open space exclusively belonging thereto; this space besides securing through ventilation will serve as a yard in which the necessary sanitary conveniences may be placed at a proper distance from the house.

In some places there may be exceptional circumstances which would render it unnecessary to require the provision of the amount of open space referred to—*e.g.*, the case of dwelling-houses abutting upon a park or other open space dedicated to the public. The Board have not provided for this either in the present model or in the urban model byelaws, but on being informed of the facts in cases of the kind or other cases of difficulty in a particular district, they would be prepared to consider additions to, or modifications of, the byelaw to meet the special circumstances.

Ventilation of Buildings.

Byelaws 8–12 deal with the ventilation of buildings, and represent the minimum requirements which the Board are advised to be necessary. It will be seen that they do not impose any undue restrictions on the position or shape of windows or fireplaces. It is very desirable that some at least of the bedrooms in all houses shall be provided with fireplaces, but this object cannot be directly secured by byelaw.

It may be pointed out that the object of byelaw 10 is to secure the ventilation of the space between the ground surface beneath the building, for the purpose of dispersing any damp or foul air which may collect there, and of preserving the timbers from decay. It is desirable that an ampler space should be provided where the ground surface is not covered with an asphalte or concrete layer, since the natural soil is always more or less porous and retentive of moisture.

Drainage of Buildings.

Byelaw 13 requires the drainage of the subsoil of a new building. It will only need to be observed in cases where the site is naturally damp.

Byelaw 14 makes provision for carrying away rain water falling on the roof of a building in such a manner as to prevent dampness in the walls or foundations of the building.

Byelaw 15 requires that the lowest storey of a building shall not be placed at such a level as will prevent its being drained.

Byelaws 16 and 18 make the necessary provision as to the material and structure of drains which are to convey foul water or sewage matter.

Byelaws 17 and 20 require the provision of suitable traps to drains to prevent the access of foul air to a building, and impose certain conditions as to inlets to drains.

Byelaw 19 provides for the necessary ventilation of drains conveying sewage matter. There is a relaxation of its requirements in cases where there is no watercloset in the building and connected with the drain, and the drain is of limited length.

Waterclosets, Earthclosets, Privies, Ashpits, and Cesspools.

The succeeding byelaws 21–43 relating to waterclosets, earthclosets, privies, ashpits and cesspools, apply to the new construction of these conveniences in all cases, whether in connection with a new or an old building. The byelaws do not require the construction of these conveniences, &c., but merely regulate their construction where they are provided. The omission of a byelaw as to any one of them would have the effect of leaving the particular construction unregulated, and would not prevent its erection.

Byelaws 21–25, relating to waterclosets, do not call for any detailed remarks.

Byelaws 26–33 relate to earthclosets and privies.

It will be observed that similar provisions have been made applicable to both earthclosets and privies. In the earlier model byelaws issued by the Board a distinction is drawn between the two kinds of conveniences, but the Board are advised that, except where an earthcloset is carefully attended to and proper arrangements are made for the supply of dry earth (not ashes), it is apt to be treated merely as a privy. In general, no distinction can usefully be made, but it is of course open to a Rural District Council, who are prepared to undertake the supply of dry earth, or who can show that facilities for obtaining it exist, to propose the adoption of byelaws dealing with earthclosets apart from privies, and for this purpose they are referred to the clauses on the subject in the existing urban model byelaws.

Byelaw 26 requires an earthcloset or privy to be placed at a distance of 10 feet at least from a dwelling house or public building, or a building in which any person may be employed, &c. In the existing model this distance is six feet, but the Board are advised that on sanitary grounds it is desirable that a greater distance should be secured, and they suggest that ten feet is a reasonable minimum distance in a rural district, and such as could always be obtained. Indeed, a Council might consider whether a greater distance might not reasonably be required.

Byelaw 27. This is for the protection of water supplies, and the Board regard it as of considerable importance. The Board have not inserted any distance in the byelaw, but suggest that the Council should fix the greatest distance which the circumstances of the district render reasonable—40 feet is the distance commonly adopted. It must be remembered that the consequences of a

pollution of a water supply arising from a defective or badly managed privy, &c., are so serious that the utmost precautionary measures should be taken to prevent such a result.

The remaining byelaws as to earthclosets and privies deal with details of construction to secure their convenient and cleanly use.

Byelaw 32. The principles to be held in view are that the receptacle of the privy should be of the smallest practicable dimensions, having regard to the facilities for the periodical removal of its contents; that with a view to secure dryness of the contents it should be of impervious construction and entirely above the ground level, and be covered so as to exclude rainfall; and that it should be provided with means for the application of earth or ashes to the excrement, and with means of access for the removal of the contents from the outside, so that the laborious and offensive operation of working in the pit may be avoided.

Byelaws 34–39 deal with the construction of ash-pits. As regards byelaws 34 and 35, the Board would refer the Council to the remarks above on byelaws 26 and 27. Similar considerations apply to the fixing of the distances in these clauses.

Byelaws 40–43 deal with the construction of cesspools. The Council should themselves insert the distances in byelaws 40 and 41 having regard to the circumstances of their district. The distance to be prescribed should be reasonable but should be adequate to ensure efficient protection for the purposes of the byelaws. The Board may say that in cases that have come before them they have advised minimum distances of 50 and 60 feet respectively in corresponding byelaws.

Closing of Buildings unfit for human habitation; the giving of notices and the deposit of plans; penalties, &c.

Byelaw 44 deals with the closing of buildings, &c., unfit for human habitation. The remaining byelaws deal with the giving of notices and the deposit of plans in cases to which the byelaws relate, the imposition of penalties for offences, and the pulling down of buildings which infringe the byelaws.

Procedure to be observed in making byelaws.

6. Any byelaws that are proposed should be submitted to the Board in the first instance in draft for their preliminary approval before any steps are taken for the printing or for the formal adoption of the byelaws. Draft forms for this purpose in which the byelaws are printed on foolscap paper with half-margin for notes will be supplied to Local Authorities on application.

Any clauses in addition to or in substitution for those of the model series should be inserted in the draft on separate sheets of paper with half-margin; minor alterations may be suitably shown in the margin of the model forms. It would be convenient to the Board if the draft byelaws were submitted in duplicate.

When the final revision of the draft has been completed, and the Rural District Council have been informed of the decision of the Board with regard to the allowance or disallowance of the several clauses, the byelaws may conveniently be printed. The formal adoption of the byelaws under the seal of the Council should then take place and the sealed print of the byelaws should be submitted to the Board for formal confirmation after compliance with the statutory requirements. The following instructions should be observed :—

Before application for confirmation is made, not less than one calendar month's notice of the intention to apply must, in pursuance of section 184 of the Act of 1875, be given in at least one local newspaper circulating in the rural district ; and, for a full calendar month after the date of the publication of this notice in the newspaper, a copy of the byelaws must be deposited at the office of the Rural District Council for the inspection of the ratepayers.

The byelaws must be kept deposited at the place described in the notice for a full calendar month after the date of publication of the newspaper in which the notice appears.

It is essential that the copy of the byelaws so deposited should be correct, as any material error would involve a fresh compliance with the statutory requirements before confirmation could take place. If it is thought desirable the draft approved by the Board may be deposited.

Urban Powers.

7. If a Rural District Council desire to obtain urban powers by an order of the Local Government Board they should pass a resolution authorising an application to be made to the Board under section 276 of the Act of 1875, or section 5 of the Act of 1890, as the case may be, for an order investing them with such powers. The resolution should specify the provisions which it is desired to put in force, and the particular contributory places in respect of which the powers are sought.

A copy of the resolution should be sent to the Board, together with a brief statement of the grounds upon which the application is made.

If any such application is made with reference to section 157 of the Act of 1875 it should extend to section 158 of the Act also, unless section 23 (3) of the Act of 1890 is already in force.

If powers under section 23 of the Act of 1890 are desired the Council should consider the desirability of including the powers of sections 25 and 33 of the same Act in the application.

S. B. Provis,
Secretary.

Local Government Board,
May, 1903.

NOTE.—*Any local authority proposing to make byelaws on this subject should apply to the Local Government Board for a form on which to submit a draft of the byelaws for the Board's preliminary approval.*

Model Byelaws, Series IV. (*a*).

Rural District Councils (53 *and* 54 *Vict. c.* 59, *s.* 23 (3)).

(*Draft form.*)

BYELAWS

made by the Rural District Council of
with respect to [1]

NEW BUILDINGS and certain matters in connection with BUILDINGS in [2]

INTERPRETATION OF TERMS.

1. In the construction of these byelaws the following words and expressions shall have the meanings herein-after respectively assigned to them, unless the context otherwise requires; that is to say,—

'District' means [2]

'Council' means the Rural District Council of

'Public building' means a building used or constructed or adapted to be used, either ordinarily or occasionally, as a church, chapel, or other place of public worship, or as a hospital, workhouse, college, school (not being merely a dwelling-house so used), theatre, public hall, public concert room, public ball-room, public lecture room, or public exhibition room, or as a public place of assembly for persons admitted thereto, by tickets or otherwise, or used or constructed or adapted to be used, either ordinarily or occasionally, for any other public purpose:

[1] Insert 'New Streets and,' if any byelaws as to new streets are repealed by Clause 52.

[2] Insert 'the Rural District of ,' or, if the byelaws are to apply to part only of a rural district, 'that portion of the Rural District of which comprises the contributory places of .'

'Building of the warehouse class' means a warehouse, factory, manufactory, brewery or distillery:

'Domestic building' means a dwelling-house or an office building, or other out-building appurtenant to a dwelling-house, whether attached thereto or not, or a shop, or any other building not being a public building, or of the warehouse class:

'Dwelling-house' means a building used or constructed or adapted to be used wholly or principally for human habitation.

Exempted Buildings.

2. The following buildings shall be exempt from the operation of these byelaws:—

(*a.*) Any building in His Majesty's possession, or employed or intended to be employed for His Majesty's use or service:

(*b.*) Any county or borough lunatic asylum, and any building belonging to the council of any county, city or borough and used or intended to be used wholly or in part for the detention of any prisoners:

(*c.*) Any gaol, house of correction, bridewell, penitentiary, or other prison, and any building occupied or intended to be occupied by any prison officer for the use of such prison and contiguous thereto:

(*d.*) Any building (not being a dwelling-house) belonging to any person or body of persons authorised by virtue of any Act of Parliament to navigate on or use any river, canal, dock, harbour, or basin, or to demand any tolls or dues in respect of the navigation of such river or canal, or the use of such dock, harbour, or basin, and used or intended to be used exclusively under the provisions of such Act of Parliament for the purposes of such river, canal, dock, harbour, or basin:

(*e.*) Any building (not being a dwelling-house) erected or intended to be erected in connection with any mine, and used or intended to be used exclusively for the working of such mine:

(*f.*) Any building erected or intended to be erected according to plans previously approved by the Land Commissioners for England or the Board of Agriculture or the Board of Agriculture and Fisheries under the Improvement of Land Act, 1864, or other Act or Acts for the improvement of land:

(*g.*) Any building which may not be exempt by the operation of any of the preceding clauses of this byelaw, and which may be erected or may be intended to be erected in accordance with such plan and in such manner as may be approved or directed in pursuance of any statutory provision in that behalf by one of His Majesty's Principal Secretaries of State:

(*h.*) Any building which shall not be a public building or a building of the warehouse class, and shall not be constructed or

adapted to be used either wholly or partly for human habitation, or as a place of habitual employment for any person in any manufacture, trade, or business, and which if intended for use as a pigstye or a cowhouse shall be detached from any dwelling house:

(*i.*) Any building erected or intended to be erected for use solely as a temporary hospital for the reception and treatment of persons suffering from any dangerous infectious disorder.

WITH RESPECT TO THE STRUCTURE OF WALLS AND FOUNDATIONS OF NEW BUILDINGS FOR PURPOSES OF HEALTH.

3. Every person who shall erect a new domestic building shall cause the whole ground surface or site of such building within the external walls to be properly asphalted or covered with a layer of good cement concrete, rammed solid, at least *six inches* thick, wherever the dampness of the site or the nature of the soil renders such a precaution necessary.

4. Every person who shall erect a new public building or a new dwelling-house shall cause every wall of such building to have a proper damp course of sheet lead, asphalte, or slates laid in cement, or of other durable material impervious to moisture, beneath the level of the lowest floor, and at a height of not less than *six inches* above the surface of the ground adjoining such wall.

Provided always that where any part of a floor of the lowest storey of such building, not being a cellar, shall be intended to be below the level of the surface of the ground immediately adjoining the exterior of such storey, and so that the ground will be in contact with the exterior of any wall, he shall cause such storey or such part thereof as will be so in contact to be constructed with walls impervious to moisture or with double walls, having an intervening cavity between such walls, of a width of *two and a half inches*, and extending from the base of such walls to a height of *six inches* above the surface of the ground immediately adjoining the exterior of such storey.

He shall cause such double walls to be properly tied together with suitable and sufficient ties of iron, tarred and sanded, galvanised iron, vitrified stoneware, or other suitable material, inserted at distances apart not exceeding *three feet* horizontally and *eighteen inches* vertically. He shall also cause a proper damp course of sheet lead, asphalte, or slates laid in cement, or of other durable material impervious to moisture, to be inserted in every such wall at the base of such wall and likewise at the level of the top of the cavity.

5. Every person who shall erect a new building shall cause every wall of such building, when carried up above any roof, flat, or gutter, so as to form a parapet, to be properly coped or otherwise protected, in order to prevent water from running down the sides of such parapet, or soaking into such wall.

WITH THE RESPECT TO THE SUFFICIENCY OF THE SPACE ABOUT BUILDINGS TO SECURE A FREE CIRCULATION OF AIR, AND WITH RESPECT TO THE VENTILATION OF BUILDINGS.

6. Every person who shall erect a new domestic building shall provide in front of such building an open space, which, measured to the boundary of any lands or premises immediately opposite, or to the opposite side of any street which may not be less than *twenty-four feet* in width where such building may front thereon, shall, throughout the whole line of frontage of such building, extend to a distance of *twenty-four feet* at the least; such distance being measured in every case at right angles to the external face of any wall of such building which shall front or abut on such open space.

Where a new domestic building may be intended to front on a street laid out before the confirmation of these byelaws, and of a less width than *twenty-four feet*, the person who shall erect such building shall provide in front thereof an open space, which, measured to the opposite side of such street throughout the whole line of frontage of such building, shall extend to a distance equal at least to the width of such street, together with *one-half* of the difference between such width and *twenty-four feet*.

Any open space provided in pursuance of this byelaw shall be free from any erection thereon above the level of the ground, except any portico, porch, step, or other like projection from such building, or any gate, fence, or wall not exceeding *seven feet* in height.

A person who shall make any alteration in or addition to such building shall not, by such alteration or addition, diminish the extent of open space provided in pursuance of this byelaw in connection with such building.

7. (1.) Every person who shall erect a new domestic building shall provide in the rear of such building an open space exclusively belonging to such building, and of an aggregate extent of not less than *one hundred and fifty square feet*, and free from any erection thereon above the level of the ground, except a watercloset, earth-closet, or privy, and an ashpit.

(2.) He shall cause such open space to extend, laterally, throughout the entire width of such building, and he shall cause the distance across such open space from every part of such building to the boundary of any lands or premises immediately opposite or adjoining the site of such building, to be *not less in any case than fifteen feet*.

If the height of such building be *twenty-five feet* he shall cause such distance to be *twenty feet* at the least.

If the height of such building be *thirty-five feet* or exceed *thirty-five feet* he shall cause such distance to be *twenty-five feet* at the least.

(3.) A person who shall make any alteration in or addition to such building shall not, by such alteration or addition, diminish the aggregate extent of open space provided in pursuance of this byelaw in connection with such building, or in any other respect fail to comply with any provision of this byelaw.

(4.) For the purposes of this byelaw the height of such building shall be the height of the highest portion of the building, measured upwards from the level of the ground over which such open space shall extend to the level of half the vertical height of the roof or to the top of the parapet, whichever may be the higher.

8. Every person who shall erect a new domestic building shall construct in the wall of each storey of such building which shall immediately front or abut on such open spaces as, in pursuance of the byelaws in that behalf, shall be provided in connection with such building, a sufficient number of suitable windows, in such a manner and in such a position that each of such windows shall afford effectual means of ventilation by direct communication with the external air.

9. Every person who shall erect a new domestic building shall construct in every habitable room of such building one window, at the least, opening directly into the external air, and he shall cause the total area of such window, or, if there be more than one, of the several windows, clear of the sash frames, to be equal at the least to *one tenth* of the floor area of such room.

Such person shall also construct every such window so that *one half*, at the least, may be opened, and so that the opening may extend in every case to the top of the window.

10. Every person who shall erect a new domestic building shall so construct every room which shall be situated in the lowest storey of such building, and shall be provided with a boarded floor, that there shall be, for the purpose of ventilation between the under side of every joist on which such floor may be laid, and the upper surface of the ground or of the asphalte or concrete with which such ground is covered, a clear space of *three inches* at the least in every part, if such ground be covered with asphalte or concrete, and of *nine inches* at the least in every part if such ground be not so covered, and he shall cause such space to be thoroughly ventilated by means of suitable and sufficient air-bricks, or by some other effectual method.

11. Every person who shall erect a new domestic building shall cause every habitable room of such building which is without a fireplace, and a flue properly constructed and properly connected with such fireplace, to be provided with special and adequate means of ventilation by a sufficient aperture or air shaft which shall provide an unobstructed sectional area of *fifty square inches* at the least.

12. Every person who shall erect a new public building shall cause such building to be provided with adequate means of ventilation.

With respect to the drainage of buildings.

13. Every person who shall erect a new building shall cause the subsoil of the site of such building to be effectually drained by

means of suitable earthenware field pipes, properly laid to a suitable outfall, wherever the dampness of the site renders such a precaution necessary.

He shall not lay any such pipe in such a manner or in such a position as to communicate directly with any sewer or cesspool, or with any drain constructed or adapted to be used for conveying sewage.

14. Every person who shall erect a new building shall, for the purpose of carrying from the roof or flat of such building all water which may fall thereon cause a suitable pipe or trunk, extending from the roof or flat to the ground, to be fixed to the front or rear or to one of the sides of such building, and to be connected with a gutter, shoot, or trough which shall be provided, constructed, and fixed in such a manner and in such a situation as to receive all water that may fall on the roof or flat.

15. Every person who shall erect a new building shall construct the lowest storey of such building at such a level that it may be practicable to construct a drain sufficient for the effectual drainage of such building and to provide the requisite communication with any sewer.

16. (1.) Every person who shall erect a new building shall, in the construction of every drain of such building, other than a drain constructed in pursuance of the byelaw in that behalf for the drainage of the subsoil of the site of such building, use good sound pipes formed of glazed stoneware, or of other equally suitable material.

(2.) He shall cause every such drain to be of adequate size, and if constructed or adapted to be used for conveying sewage to have an internal diameter not less than *four inches*, and to be laid where necessary in a bed of good concrete, with a proper fall, and with socketed or other suitable watertight joints.

(3.) He shall not construct any such drain so as to pass under any building, except in any case where any other mode of construction may be impracticable.

In that case, he shall cause such drain to be laid in a direct line for the whole distance beneath such building, and to be completely embedded in and covered with good and solid cement concrete, at least *six inches* thick, all round.

He shall also cause adequate means of access to be provided in connection with such drain at each end of such portion thereof as is beneath such building.

(4.) He shall cause every inlet to any drain, not being an inlet provided in pursuance of the byelaw in that behalf as an opening for the ventilation of such drain, to be properly trapped.

17. Every person who shall erect a new building shall provide, within the curtilage thereof, in every main drain or other drain of such building which may directly communicate with any sewer or other means of drainage into which such drain may lawfully empty, a suitable trap at a point as distant as may be practicable from

such building and as near as may be practicable to the point at which such drain may be connected with such sewer or other means of drainage.

18. A person who shall erect a new building shall not construct the several drains of such building in such a manner as to form in such drains any right-angled junction. He shall cause every branch drain or tributary drain to join another drain obliquely in the direction of the flow of such other drain.

19. Every person who shall erect a new building shall, for the purpose of securing efficient ventilation of the several drains of such building constructed or adapted to be used for conveying sewage, comply with the following requirements :—

(1.) He shall provide at least two untrapped openings to such drains, of which openings one shall be situated as near as may be practicable to the trap which, in pursuance of the byelaw in that behalf, shall be provided between the main drain or other drain of the building, and the sewer or other means of drainage with which such drain may lawfully communicate, and on that side of the trap which is the nearer to the building ; and the second opening shall be as far distant as may be practicable from the point at which the first-mentioned opening shall be situated.

One of the aforesaid openings shall be at or near the level of the surface of the ground adjoining such opening, and shall communicate with the drains by means of a suitable pipe, shaft, or disconnecting chamber.

The other opening shall be obtained by carrying up a pipe or shaft, vertically, to such a height and in such a manner as effectually to prevent any escape of foul air from such pipe or shaft into any building in the vicinity thereof, and in no case to a less height than *ten feet*.

Provided always, that the soil pipe of any watercloset, in every case where the situation, sectional area, height, and mode of construction of such soil pipe shall be in accordance with the requirements applicable to the pipe or shaft to be carried up from the drains, may be deemed to provide the necessary opening for ventilation which would otherwise be obtained by means of such last-mentioned pipe or shaft.

(2.) He shall cause every opening provided in accordance with the arrangements herein-before specified to be furnished with a suitable grating or other suitable cover for the purpose of preventing any obstruction in or injury to any pipe or drain by the introduction of any substance through any such opening. He shall, in every case, cause such grating or cover to be so constructed and fitted as to secure the free passage of air through such grating or cover by means of a sufficient number of apertures, of which the aggregate extent shall be not less than the sectional area of the pipe or drain to which such grating or cover may be fitted.

(3.) Every pipe or shaft which may be used in connection with the arrangements herein-before specified shall be of a sectional area

not less than that of the drain with which such pipe or shaft may communicate.

Provided that where such pipe or shaft communicates with a drain of an internal diameter of *four inches*, the internal diameter of such pipe or shaft may be not less than *three and a half inches*.

(4.) No bend or angle shall (except where unavoidable) be formed in any pipe or shaft used in connection with the arrangements herein-before specified.

(5.) Provided that—

(*a.*) Where there is no watercloset within the building and connected with the drain and the drain shall not be more than *twenty feet* in length, the requirements of this byelaw shall not apply to the case;

(*b.*) Where the aggregate length of so much of the drain or drains of a new building as is above the trap to be provided in pursuance of the byelaw in that behalf in every main drain or other drain of such building which may directly communicate with any sewer or other means of drainage into which such drain may lawfully empty, shall not exceed *thirty feet*, and such drain or any of such drains shall not be connected with any water-closet which has internal communication with any building, the opening required by this byelaw to be provided at or near the level of the surface of the ground may be dispensed with.

20. (1.) A person who shall erect a new building shall not construct any drain of such building in such a manner as to allow any inlet to such drain (except such inlet as may be necessary from the apparatus of any watercloset or any slop sink constructed or adapted to be used for receiving within such building any solid or liquid filth) to be made within such building.

(2) He shall cause the soil pipe from every watercloset in such building to be at least *three and a half inches* in diameter.

(3) He shall cause such soil pipe, and the waste pipe from every such slop sink, to be fixed outside such building, and to be continued upwards without diminution of its diameter, and (except where unavoidable) without any bend or angle being formed in such soil pipe or waste pipe to such a height and in such a position as to afford, by means of the open end of such soil pipe or waste pipe, an outlet for foul air at a safe distance from windows, chimneys, and other openings.

(4) He shall so construct such soil pipe or waste pipe that there shall not be any trap between such soil pipe or waste pipe and the drains, or any trap (other than such as may necessarily form part of the apparatus of any watercloset or slop sink) in any part of such soil pipe or waste pipe.

(5) He shall cause the waste pipe from every bath, sink (not being a slop sink constructed or adapted to be used for receiving any solid or liquid filth), or lavatory, and every pipe in such building for carrying off foul waste water to be properly trapped, and to be

taken through an external wall of such building, and to discharge in the open air over a channel leading to a trapped gully grating.

(6) He shall cause the overflow pipe from any cistern and from every safe under any bath or watercloset to be taken through an external wall of such building, and to discharge in the open air.

WITH RESPECT TO WATERCLOSETS IN CONNECTION WITH BUILDINGS, AND WITH RESPECT TO THE KEEPING OF WATERCLOSETS SUPPLIED WITH SUFFICIENT WATER FOR FLUSHING.

21. Every person who shall construct a watercloset within a building shall construct such watercloset in such a position that one of its sides at the least shall be an external wall.

22. Every person who shall construct a watercloset within a building shall construct in one of the walls of such watercloset a window of not less dimensions than *two feet* by *one foot*, exclusive of the frame, and opening directly into the external air.

He shall, in addition to such window, cause such watercloset to be provided with adequate means of constant ventilation by at least one air-brick built in an external wall of such watercloset, or by an air shaft, or by some other effectual method or appliance.

23. Every person who shall construct a watercloset in connection with but not within a building shall cause the same to be provided with a sufficient opening for lighting and ventilation, as near to the top as convenient and communicating directly with the external air.

24. Every person who shall construct a watercloset in connection with a building shall furnish such watercloset with a separate cistern or flushing box of adequate capacity, which shall be so constucted, fitted, and placed as to admit of the supply of water for use in such watercloset without any direct connection between any service pipe upon the premises and any part of the apparatus of such watercloset, other than such cistern or flushing box.

He shall furnish such watercloset with a suitable apparatus for the effectual application of water to any pan, basin, or other receptacle with which such apparatus may be connected and used, and for the effectual flushing and cleansing of such pan, basin, or other receptacle, and for the prompt and effectual removal therefrom of any solid or liquid filth which may from time to time be deposited therein.

He shall furnish such watercloset with a pan, basin, or other suitable receptacle of non-absorbent material, and of such shape, of such capacity, and of such mode of construction as to receive and contain a sufficient quantity of water, and to allow all filth which may from time to time be deposited in such pan, basin, or receptacle to fall free of the sides thereof, and directly into the water received and contained in such pan, basin, or receptacle.

He shall not construct or fix under such pan, basin, or receptacle any 'container' or other similar fitting.

He shall not construct or fix in or in connection with the water-closet apparatus any trap of the kind known as a 'D' trap.

25. The occupier of any premises shall, throughout any period during which any person may inhabit the premises, or may be employed therein in any manufacture, trade, or business, cause every watercloset provided on or in connection with the premises to be supplied with a sufficient quantity of water for the proper flushing of such watercloset:

Provided that, where there are two or more occupiers of the premises on or in connection with which any such watercloset is provided, the foregoing requirement shall apply to such one or more of the said occupiers as, according to the terms and conditions of his or their occupation of the premises, may have the exclusive or joint control of the watercloset.

With respect to earthclosets and privies in connection with buildings.

26. Every person who shall construct an earthcloset or a privy in connection with a building shall construct such earthcloset or privy at a distance of *ten feet* at the least from a dwelling-house or public building, or any building in which any person may be, or may be intended to be, employed in any manufacture, trade, or business.

27. A person who shall construct an earthcloset or a privy in connection with a building shall not construct such earthcloset or privy within the distance of *feet* from any well, spring, or stream of water used or likely to be used by man for drinking or domestic purposes, or for manufacturing drinks for the use of man, or otherwise in such a position as to render any such water liable to pollution.

28. Every person who shall construct an earthcloset or a privy in connection with a building shall construct such earthcloset or privy in such a manner and in such a position as to afford ready means of access to such earthcloset or privy, for the purpose of cleansing such earthcloset or privy and of removing filth therefrom, and in such a manner and in such a position as to admit of all filth being removed from such earthcloset or privy, and from the premises to which it may belong, without being carried through any dwelling-house or public building or any building in which any person may be, or may be intended to be, employed in any manufacture, trade, or business.

29. Every person who shall construct an earthcloset or a privy in connection with a building shall provide such earthcloset or privy with a sufficient opening for light and ventilation, as near to the top as convenient, and communicating directly with the external air.

He shall cause the floor of such earthcloset or privy to be flagged or paved with hard tiles or other non-absorbent material, and he

shall construct such floor so that it shall be in every part thereof at a height of not less than *six inches* above the level of the surface of the ground adjoining such earthcloset or privy, and so that such floor shall have a fall or inclination towards the door of such earthcloset or privy of *half an inch* to the *foot*.

30. Every person who shall construct an earthcloset or a privy in connection with a building shall provide, construct, or fix in or in connection with such earthcloset or privy suitable means or apparatus for the frequent and effectual application of dry earth, or other deodorising substance, or of ashes, dust, or dry refuse, to any filth which may from time to time be deposited in the receptacle of such earthcloset or privy.

31. Every person who shall construct an earthcloset or privy in connection with a building, and shall construct such earthcloset or privy for use in combination with a movable receptacle for filth, shall construct over the whole area of the space immediately beneath the seat of such earthcloset or privy a floor flagged or asphalted or concreted and rendered in cement, at a height of less than *three inches* above the level of the surface of the ground adjoining such earthcloset or privy; and he shall cause the whole extent of each side of such space between the floor and the seat to be constructed of such materials and in such manner as to prevent any absorption by any part thereof of any filth deposited in such earthcloset or privy.

He shall construct the seat of such earthcloset or privy, the aperture in such seat, and the space beneath such seat, of such dimensions as to admit of a movable receptacle for filth of a capacity not exceeding *two cubic feet* being placed and fitted beneath such seat in such a manner and in such a position as may effectually prevent the deposit, upon the floor or sides of the space beneath such seat or elsewhere than in such receptacle, of any filth which may from time to time fall or be cast through the aperture in such seat.

He shall construct the seat of such earthcloset or privy so that the whole of such seat, or a sufficient part thereof, may be readily removed or adjusted in such a manner as to afford adequate access to the space beneath such seat for the purpose of cleansing such space, or of removing therefrom or placing and fitting therein the appropriate receptacle for filth, or shall otherwise provide adequate means of access to such space for the purposes aforesaid.

32. Every person who shall construct an earthcloset or a privy in connection with a building, and shall construct such earthcloset or privy for use in combination with a fixed receptacle for filth, shall construct such receptacle so that the contents thereof may not at any time be exposed to any rainfall or the drainage of any waste water or liquid refuse from any adjoining premises.

He shall construct such receptacle of such material or materials and in such a manner as to prevent any absorption by any part of such receptacle of any filth deposited therein or any escape,

by leakage or otherwise, of any part of the contents of such receptacle.

He shall construct such receptacle so that the bottom or floor thereof shall be in every part at least *three inches* above the level of the surface of the ground adjoining such receptacle.

He shall not in any case construct such receptacle of a capacity exceeding *twelve cubic feet*.

He shall construct the seat of such earthcloset or privy so that the whole of such seat, or a sufficient part thereof, may be readily removed or adjusted in such a manner as to afford adequate access to such receptacle for the purpose of removing the contents thereof, and of cleansing such receptacle, or shall otherwise provide adequate means of access to such receptacle for the purpose aforesaid.

33. A person who shall construct an earthcloset or a privy in connection with a building shall not cause or suffer any part of the space under the seat of such earthcloset or privy, or any part of any receptacle for filth in or in connection with such earthcloset or privy to communicate with any drain.

WITH RESPECT TO ASHPITS IN CONNECTION WITH BUILDINGS.

34. Every person who shall construct an ashpit in connection with a building shall construct such ashpit at a distance of *ten feet* at the least from a dwelling-house or public building, or any building in which any person may be, or may be intended to be, employed in any manufacture, trade, or business.

35. A person who shall construct an ashpit in connection with a building shall not construct such ashpit within the distance of *feet* from any well, spring, or stream of water used or likely to be used by man for drinking or domestic purposes, or for manufacturing drinks for the use of man, or otherwise in such a position as to render any such water liable to pollution.

36. Every person who shall construct an ashpit in connection with a building shall construct such ashpit in such a manner and in such a position as to afford ready means of access to such ashpit for the purpose of cleansing such ashpit, and of removing the contents thereof, and, so far as may be practicable, in such a manner and in such a position as to admit of the contents of such ashpit being removed therefrom, and from the premises to which such ashpit may belong, without being carried through any dwelling-house or public building, or any building in which any person may be, or may be intended to be, employed in any manufacture, trade, or business.

37. Every person who shall construct an ashpit in connection with a building shall construct such ashpit of a capacity not exceeding in any case *twenty cubic feet*, or of such less capacity as may be sufficient to contain all dust, ashes, rubbish, and dry refuse which may accumulate during a period not exceeding *one month* upon the premises to which such ashpit may belong.

38. Every person who shall construct an ashpit in connection

with a building shall construct such ashpit of flagging, or of slate, or of good brickwork, at least *nine inches* thick, and rendered inside with good cement or properly asphalted.

He shall construct such ashpit so that the floor thereof shall be at a height of not less than *three inches* above the surface of the ground adjoining such ashpit, and he shall cause such floor to be properly flagged or asphalted or concreted and rendered in cement.

He shall cause such ashpit to be properly roofted over and ventilated, and to be furnished with a suitable door in such a position and so constructed and fitted as to admit of the convenient removal of the contents of such ashpit, and to admit of being securely closed and fastened for the effectual prevention of the escape of any of the contents of such ashpit.

39. A person who shall construct an ashpit in connection with a building shall not cause or suffer any part of such ashpit to communicate with any drain.

WITH RESPECT TO CESSPOOLS IN CONNECTION WITH BUILDINGS.

40. Every person who shall construct a cesspool in connection with a building shall construct such cesspool at a distance of *feet* at the least from any dwelling-house or public building, or any building in which any person may be, or may be intended to be, employed in any manufacture, trade, or business.

41. A person who shall construct a cesspool in connection with a building shall not construct such cesspool within the distance of *feet* from any well, spring, or stream of water used or likely to be used by man for drinking or domestic purposes, or for manufacturing drinks for the use of man, or otherwise in such a position as to render any such water liable to pollution.

42. Every person who shall construct a cesspool in connection with a building shall construct such cesspool in such a manner and in such a position as to afford ready means of access to such cesspool for the purpose of cleansing such cesspool, and of removing the contents thereof, and in such a manner and in such a position as to admit of the contents of such cesspool being removed therefrom, and from the premises to which such cesspool may belong, without being carried through any dwelling-house or public building, or any building in which any person may be, or may be intended to be, employed in any manufacture, trade, or business.

He shall not in any case construct such cesspool so that it shall have, by drain or otherwise, any outlet into or means of communication with any sewer.

43. Every person who shall construct a cesspool in connection with a building shall construct such cesspool of good brickwork in cement, properly rendered inside with cement, and with a backing of at least *nine inches* of well puddled clay or of at least *six inches* of good cement concrete around and beneath such brickwork, or shall otherwise construct such cesspool of suitable material and so as to be impervious to liquid.

He shall also cause such cesspool to be arched or otherwise properly covered over, and to be provided with adequate means of ventilation.

WITH RESPECT TO THE CLOSING OF BUILDINGS OR PARTS OF BUILDINGS UNFIT FOR HUMAN HABITATION, AND TO PROHIBITION OF THEIR USE FOR SUCH HABITATION.

44. In every case :—

Where, by a notice in writing in the form hereunto appended, or to the like effect, and signed by the clerk to the Council, and duly served upon or delivered to the owner of a building or part of a building erected after the [1] *date of the confirmation of these byelaws*, the Council shall certify that it has been represented to them that such building or part of a building is unfit for human habitation, and that, unless on or before such day as shall be specified in such notice, such owner, by a statement in writing under his hand or under the hand of his agent duly authorised in that behalf, and addressed to and duly served upon or delivered to the Council, shall show sufficient cause why such building or part of a building shall not be declared unfit for human habitation, or unless, on such day and at such time and place as shall be specified in such notice, such owner personally or by his agent duly authorised in that behalf shall attend before the Council and show sufficient cause why such building or part of a building shall not be declared unfit for human habitation, the Council will declare such building or part of a building unfit for human habitation, and direct that such building or part of a building shall be closed, and prohibit the use for human habitation of such building or part of a building until the same shall have been rendered fit for human habitation :

And where such owner shall fail to show sufficient cause why such building or part of a building shall not be declared unfit for human habitation, and where, in consequence of such failure, the Council by their order, which shall be in writing under their seal in the form hereunto appended, or to the like effect, and shall be duly signed by their clerk, and which, or a copy of which shall be affixed in some conspicuous position in or upon such building or part of a building, may declare that such building or part of a building is unfit for human habitation, and may direct that, unless and until such building or part of a building shall have been rendered fit for human habitation, the same shall be closed, and the use thereof for human habitation shall be prohibited :—

A person shall not, after the date specified in such order and before such building or part of a building shall have been rendered fit for human habitation, knowingly inhabit or continue to inhabit, or knowingly cause or suffer to be inhabited such building or part of a building.

[1] If byelaws as to new buildings are already in force, the date of the confirmation of those byelaws may be inserted here.

Form of Notice.

Rural District of

To , of

WHEREAS by a statement in writing under the hand of Medical Officer of Health of the Rural District Council of , of which statement a copy is contained in the schedule hereunto annexed, it has been certified to the said Council that a certain building or part of a building situate at in the said district is unfit for human habitation;

And whereas it has been shown to the said Council that you are the owner of such building or part of a building;

Now, , clerk to the said Council, do hereby give you notice that, unless on or before the day of 19 , by a statement in writing under your hand or under the hand of an agent duly authorized by you in that behalf, and addressed to and duly served upon or delivered to the said Council, you shall show to the said Council sufficient cause why such building or part of a building shall not be declared unfit for human habitation;

Or, unless you shall attend either personally or by an agent duly authorised in that behalf before the said Council at their office in on day the day of 19 , at o'clock in the noon, and shall then and there show to the said Council sufficient cause why such building or part of a building shall not be declared unfit for human habitation;

The said Council, in pursuance of the powers conferred upon them in that behalf, will, by an order in writing under their seal, declare that such building or part of a building is unfit for human habitation, and direct that, unless and until such building or part of a building shall have been rendered fit for human habitation, the same shall be closed, and the use thereof for human habitation shall be prohibited.

Witness my hand this day of in the year one thousand nine hundred

Clerk to the Council.

SCHEDULE.

Copy of certificate of

Form of Order.

Rural District of

To , of , and to all others whom it may concern:

WHEREAS it has been certified to us, the Rural District Council of , that a certain building or part of a building situate at in the said district is unfit for human habitation;

And whereas due notice of such certificate has been given to , the owner of such building or part of a building, and the said has failed to show sufficient cause why such building or part of a building shall not be declared unfit for human habitation;

Now we, the said Council, in pursuance of the powers conferred upon us in that behalf, do hereby declare that such building or part of a building is unfit for human habitation; and we do hereby direct that, unless and until such building or part of a building shall have been rendered fit for human habitation, the same shall be closed, and the use thereof for human habitation shall be prohibited.

Given under the common seal of the Council, this
(L.S.) day of , in the year one thousand nine hundred

Clerk to the Council.

AS TO THE GIVING OF NOTICES; AS TO THE DEPOSIT OF PLANS AND SECTIONS BY PERSONS INTENDING TO CONSTRUCT BUILDINGS AND AS TO INSPECTION BY THE COUNCIL.

45. Every person who shall intend to erect a building to which the byelaws relating to new buildings will apply shall give to the Council notice in writing of such intention, which shall be delivered or sent to their clerk at his or their office, or to their surveyor at his or their office, and shall at the same time deliver or send, or cause to be delivered or sent, to their clerk at his or their office, or to their surveyor at his or their office, plans and sections of such intended building, which shall be drawn to a scale of not less than *one inch* to every *eight feet*, and shall indicate, so far as may be necessary to show compliance with the byelaws, the position, form, and dimensions of such building, and of every watercloset, earth-closet, privy, ashpit, cesspool, well, and all other appurtenances, the damp course, the level of the lowest floor of such building and of any yard or ground belonging thereto, and in which the building shall be so described as to show whether it is intended to be used as a dwelling-house or otherwise.

Such person shall at the same time deliver or send, or cause to be delivered or sent, to the clerk to the Council at his or their office, or to their surveyor at his or their office, a description in writing of the intended mode of drainage of such building and means of water supply.

Such person shall at the same time deliver or send, or cause to be delivered or sent, to the clerk to the Council at his or their office, or to their surveyor at his or their office, a block plan of such building, to a scale of not less than *one inch* to every *forty-four feet*, and shall show the position of the buildings and appurtenances

of the properties immediately adjoining, and the width of the street, if any, in front.

Such person shall likewise show on such plan the intended lines of drainage of such building, and the intended size, depth, and inclination of each drain, and the details of the arrangement proposed to be adopted for the ventilation of the drains.

Such person shall sign such plans and sections or cause the same to be signed by his duly authorised agent.

46. Every person who shall intend to erect a building, or otherwise to execute any work to which any of the foregoing byelaws may apply, shall before beginning to erect such building, or to execute such work, deliver or send, or cause to be delivered or sent, to the surveyor of the Council at his or their office notice in writing, in which shall be specified the date on which such person will begin to erect such building, or to execute such work.

Such person shall also, before proceeding to cover up any drain deliver or send, or cause to be delivered or sent, to the surveyor of the Council at his or their office notice in writing, in which shall be specified the date on which such person will proceed to cover up such drain.

If such person neglect or refuse to deliver or send any such notice or to cause any such notice to be delivered or sent to such surveyor, and if such surveyor, on inspecting any work in connexion with such building, or such other work as aforesaid, finds that such work is so far advanced that he cannot ascertain whether anything required by any of the foregoing byelaws has been done contrary to such byelaw, or whether anything required by any of such byelaws to be done has been omitted to be done, and if, within a reasonable time after such survey or inspection, such person shall by notice in writing under the hand of such surveyor, be required within a reasonable time which shall be specified in such notice to cause so much of such work as prevents such surveyor from ascertaining whether anything has been done or omitted to be done as aforesaid to be cut into, laid open, or pulled down to a sufficient extent to enable such surveyor to ascertain whether anything has been done or omitted to be done as aforesaid, such person shall within the time specified in such notice cause such work to be so cut into, laid open, or pulled down.

47. In every case :—

Where a person who shall erect a building, or shall execute any other work to which the foregoing byelaws may apply, shall, at any reasonable time during the progress, or after the completion of the erection of such building, or the execution of such work receive from the surveyor of the Council notice in writing specifying any matters in respect of which the erection of such building, or the execution of such work may be in contravention of any such byelaw, and requiring such person within a reasonable time, which shall be specified in such notice, to cause anything done contrary to any such byelaw to be amended, or to do anything which by

any such byelaw may be required to be done, but which has been omitted to be done:—

Such person shall, within the time specified in such notice, comply with the several requirements thereof so far as such requirements relate to matters in respect of which the erection of such building, or the execution of such work may be in contravention of any such byelaw.

Such person, within a reasonable time after the completion of any work which may have been executed in accordance with any such requirement, shall deliver or send, or cause to be delivered or sent, to the surveyor of the Council at his or their office notice in writing of the completion of such work, and shall, at all reasonable times within a period of *seven days* after such notice shall have been so delivered or sent, afford such surveyor free access to such work for the purpose of inspection.

48. Every person who shall erect a building, or shall execute any other work to which any of the foregoing byelaws shall apply, shall, at all reasonable times, during the erection of such building, or the execution of such work, afford the surveyor of the Council free access to such building or work for the purpose of inspection.

49. Every person who shall erect a building or execute any work to which the foregoing byelaws apply shall, within a reasonable time after the completion of the erection of such building, or the conclusion of such work, deliver or send, or cause to be delivered or sent, to the surveyor of the Council, at his or their office, notice in writing of the completion of the erection of such building, or the conclusion of such work, and shall, at all reasonable times, within a period of *seven days* after such notice shall have been so delivered or sent, and in the case of the erection of a building before such building shall be occupied afford such surveyor free access to every part of such building or of such work for the purpose of inspection.

Penalties.

50. Every person who shall offend against any of the foregoing byelaws shall be liable for every such offence to a penalty of *five pounds*, and in the case of a continuing offence to a further penalty of *forty shillings* for each day after written notice of the offence from the Council:

Provided, nevertheless, that the justices or court before whom any complaint may be made or any proceedings may be taken in respect of any such offence may, if they think fit, adjudge the payment as a penalty of any sum less than the full amount of the penalty imposed by this byelaw.

AS TO THE POWER OF THE COUNCIL TO REMOVE, ALTER, OR PULL DOWN ANY WORK BEGUN OR DONE IN CONTRAVENTION OF THE BYELAWS.

51. If any work to which any of the foregoing byelaws may apply be begun or done in contravention of any such byelaw, the person by whom such work shall be so begun or done, by a notice in writing, which shall be signed by the clerk to the Council, and shall be duly served upon or delivered to such person, shall be required on or before such day as shall be specified in such notice by a statement in writing under his hand or under the hand of an agent duly authorised in that behalf, and addressed to and duly served upon the Council, to show sufficient cause why such work shall not be removed, altered, or pulled down; or shall be required on such day and at such time and place as shall be specified in such notice to attend personally or by an agent duly authorized in that behalf before the Council and show sufficient cause why such work shall not be removed, altered, or pulled down.

If such person shall fail to show sufficient cause why such work shall not be removed, altered, or pulled down, the Council shall be empowered, subject to any statutory provision in that behalf, to remove, alter, or pull down such work.

REPEAL OF BYELAWS.[1]

52. From and after the date of the confirmation of these byelaws, the byelaws relating to new buildings which were made on the day of in the year one thousand hundred and by the and were confirmed on the day of in the year one thousand hundred and by the Local Government Board shall be repealed, except as regards any work commenced before the date of the confirmation of this byelaw, or any work not so commenced, but of which plans shall either have been approved by the Council before such date, or have been sent to the Surveyor or Clerk to the Council one month at least before such date, and shall not have been disapproved by the Council.

[1] If there are any byelaws in force upon the subject of the foregoing clauses this clause should be filled in. If there are no byelaws in force this should be stated, and the clause should be struck out.

CHAPTER XIX

PLUMBING

SINCE there is very little building work which can be satisfactorily completed without the use of lead in some form or other, it is necessary to devote a chapter to this important subject of plumbing. As in sundry other departments of building construction, it would be possible to write very extensively upon lead work; however, there is a very great deal which need not be touched upon in a work which is particularly applied to farm and estate building construction.

Lead is prepared and produced in two marketable forms :—

1. Cast lead, which is run in a molten condition into sand moulds resulting in sheets of about 6 feet wide and 16 to 18 feet long. This variety is used where greater strength is required, but is subject to irregularities in thickness and what are called sand holes—the result of the molten lead forming bubbles.

2. Milled lead, which is produced by rolling 'pigs' of lead out into sheets of uniform thickness, which can be varied by the adjustment of the rollers. These sheets are 7 to 8 feet wide and 30 feet long. The thickness varies according to the purpose for which the lead is to be used, the usual weight for different purposes being as follows :—

For Roofs, flats, and large gutters . .	7 to 8 lb. per sq. foot
,, Small gutters, ridges, and hips . .	6 ,, ,, ,,
,, Flashings	5 to 6 ,, ,, ,,
,, Rain-water pipes, cistern and sink linings	7 ,, ,, ,,
,, Soil pipes (sewage) . . .	8 ,, ,, ,,

Wherever lead is to be laid in areas larger than those of flashings, ridges, hips, &c., a prepared boarded surface has to be made, having no sharp angles or projections and planed to a smooth surface. To allow for contraction and expansion no greater length than 12 feet in one piece should be laid, which necessitates junctions between the sheets. This is usually done by planed and rounded wood rolls, fixed to the surface of the boarding, over which the adjoining sheets

of lead lap in such a way that the roll is passed on each side by about 3 inches of a double thickness of lead. Another method is by placing the two overlapping ends side by side vertically and then folding or rolling them over and over till they touch the surface of the lead flat (Fig. 205). The use of lead in valley gutters—i.e., the points where the downward slopes of two roofs meet—is very usual. The gutters may be either tapering or box gutters. The latter type is cheaper and quite satisfactory, as the width of the gutter does not alter throughout its length, whereas in the tapering variety, the longer the roof the higher, and therefore the wider, must be the lead. In both cases, however, as will be seen from the diagrams, the method of laying is very similar—that is to say, a boarded surface is prepared and carried upon supports fixed to the feet of the rafters. The box gutter, however, requires vertical sides in addition, and the tapered gutter a series of drips, which are steps of 1 inch high, across the width. The lead at the sides of both types of gutters is

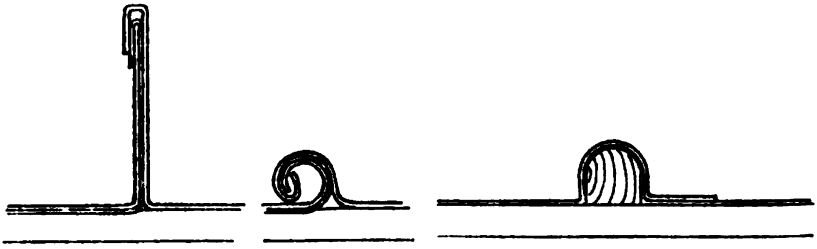


Fig. 205.

dressed up under the roof covering to make the joint perfectly watertight (Figs. 206, 207, 210).

Flashing is a system of providing by the use of lead and sometimes cement a water-tight joint at such positions as that where a chimney stack emerges from a roof, or where a roof light abuts on the tiles or slates. On the lower side of any such construction the lead having been fixed to the face of the brickwork or timber is dressed down compactly and taken over the roofing so that the rain-water is thrown over the tiles or slates below and clear of the joint. Above, the lead is dressed up underneath the roofing material and sloped either from the middle to the two ends or from one end to the other of the back of the chimney stack, roof light or whatever it may be, in order to conduct the water on to the surrounding roof. The sides remain to be rendered waterproof, and this is done by dressing the lead in raking or stepped flashings and fixing in the joints of the brickwork and down to the level of the sloping roof, either projecting for 3 or 4 inches over the slates or tiles or underneath forming a secret gutter constructed as shown in the diagrams (Figs. 208, 209).

The junctions of lead pipes also form an important part of a plumber's work, the two most generally employed being—

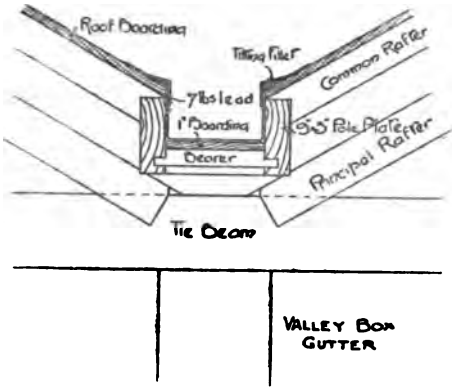


Fig. 206.

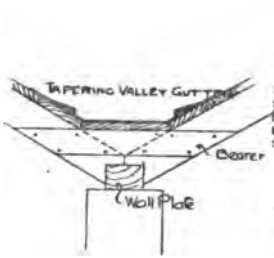


Fig. 207.

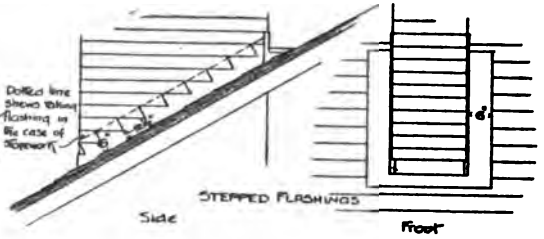


Fig. 208.

Fig. 209.

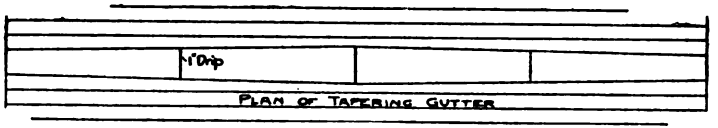


Fig. 210.

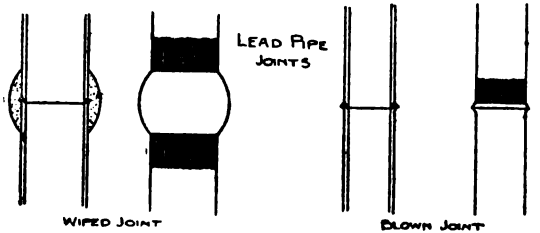


Fig. 211.

Fig. 212.

1. A blown joint which consists of the ends of two pipes being respectively opened and filed down to fit each other, the space between the two ends being filled with solder composed of one part of lead and two of tin (Fig. 212).

2. A wiped joint, used for pipes of larger diameter than above. The ends of the two pipes to be joined are prepared as in the blown joint, but the amount of solder—which in this case is composed of 1½ or 2 parts of lead to 1 of tin—extends about 2 inches above and 2 inches below (4 inches in all) the junction. The solder is carefully poured in and wiped round, the operation continuing until the joint presents the appearance shown in the diagram (Fig. 211).

PRICES

		£	s.	d.
Milled Lead cut to sizes . . .	per cwt.	1	1	0
,, ,, in gutters, flats, flashings, hips, or ridges	,,	1	6	0
,, ,, in stepped flashings, cisterns, sinks, &c.	,,	1	7	6
Allowance for old lead	,,	0	12	0

CHAPTER XX

SPECIFICATIONS, ETC.

In all cases where any building work has to be done, no matter of what size, it is nearly always necessary for the architect, or at any rate him who is responsible for the design and arrangement, to specify in writing every detail in connection therewith. For this purpose it is desirable for those who may at some time or other find themselves in such a position of responsibility to know how a specification is composed in the clearest and quickest way. Having once laboured through the building up of a specification, all subsequent compositions can well be based upon the original, and all necessary alterations in detail made according to the intentions of the designer.

Firstly, it is necessary to subdivide the whole specification into the various trades which it will be necessary to employ—such as excavator, mason, bricklayer, carpenter and joiner, glazier, &c., as shown in the specifications of either the stables or cowhouse or any of those given in this volume. This being done each trade is taken separately and every detail entered seriatim under its correct trade. As will be seen on reference to the specifications mentioned above there are sundry somewhat important preliminary and general clauses with which the specification should commence, chiefly when the work in question is to be let out to contract; and the builder chosen to carry out the work, either as a result of his tender being the lowest or by reason of his good reputation, is then easily able to comprehend his responsibility, and the specification and drawings form an agreement by which both he and his employer must stand.

There is a variety of ways in which a specification may be worded, some being somewhat verbose and others abrupt. A very usual method of writing such is instanced in those specifications already referred to.

Were it possible to clearly show in the drawings of some projected building every detail of construction and arrangement no specification would be necessary, but as can be readily understood this is not possible, and it is therefore the custom to consider the drawings and specification simultaneously, and that which is not shown or stated

in the one is to be found in the other in such a way that there should be no doubt as to the intention of the designer. Both the drawings and the specifications are signed by the selected contractor, and, as previously stated, such signature forms a lasting and inviolable agreement between him and his employer. Any alterations in either subsequent to the appending of the signatures and approved by arrangement between the two parties are additionally initialled by the builder, and have a similar effect to that of a codicil in the case of a will.

The contractor is supplied free of charge with one copy of all working drawings and specification, and subsequently such detail drawings as are necessary for the execution of any part of the work at the request of the contractor, the request being made within a reasonable time before it is necessary to execute the work in order to fulfil the contract. An architect may demand vouchers from the contractor to show that the materials are such as are specified. The method of paying for work completed can, of course, be decided by agreement between the contractor and the architect, but generally certificates are given from time to time by the latter, vouching for the fact that the contractor is entitled to receive payment in respect of, at any rate, a reasonable percentage of work satisfactorily carried out up to date. As space is necessarily limited in the present work and the question of contracts is of a lengthy nature it will perhaps be best to state that a Form of Agreement and Schedule of Conditions for Building as issued by the sanction of the R.I.B.A. in agreement with the Institute of Builders and the National Federation of Building Trade Employers of Great Britain and Ireland can be obtained at any time at the office of the Institute, 9 Conduit Street, W., at a cost of one shilling.

In cases where building work is somewhat extensive a clerk of the works is appointed by the architect under whom he acts as inspector, and who is entitled to have access at all times to any drawings or parts of the works. His function is to be on the spot throughout the carrying of the contract, to keep records and diaries, and to report periodically to the architect.

A priced bill of quantities is merely a list of all material required which states the amount and cost of each detail. In large contracts this is prepared separately by a quantity surveyor as a guide and check in the selection of the contractor who is to carry out the work. By this means it is possible to discover in the most exhaustive manner the cost of any proposed building. There are other, though not as accurate, ways of estimating, which can be utilised for the purpose of obtaining a fairly shrewd idea of the ultimate cost. The most usual is by cubing the contents: taking as the height the vertical distance from the footings to halfway up the roof and multiplying it by the length and then the breadth. Roughly, the price per cubic foot can be classed according to the type of building in question and may range for purposes of farm and estate work from 3½*d.* to 8*d.* or 9*d.* Thus, in the case of a labourer's cottage, when the cubic

contents are reckoned up the cost may be worked out at 4½*d.* per cubic foot. Another way of arriving at the probable cost is by reckoning at, say, £50 a room in a dwelling-house or £8 a cow in a stock-house. This method, however, as can be seen, is the least likely to give very reliable results and would only be used in the initial stages of anticipating the cost of some projected building.

CHAPTER XXI

RURAL COTTAGES

THE question of housing the labourer is one which has attracted an enormous amount of attention of recent years and one which has been discussed very thoroughly throughout the length and breadth of the land from every possible aspect. There is no possible doubt that it is one of extreme importance and fully justifies all the attention that it has recently attracted. But there seem to be several points which a cursory glance at the question does not cover. In a large number of cases a landlord and his territorial possessions, including the dwelling-houses thereon, are in a similar position to a manufacturer and his business. Looking at each from a business point of view, they are based upon the same idea; that is to say, the landlord's capital is invested in his possessions in a similar way to that of the manufacturer, and it is to be supposed with equal hopes of a fair percentage thereon during each year. It follows therefore that any cottages erected on his land are intended to produce economic rents, and it is these rents which are governed by the wages of the occupants. Just as a City clerk earning a very small income cannot afford to live in a house which costs him more than a certain amount no matter how extensive his family, so a labourer working on a farm cannot afford to occupy a cottage whose dimensions necessitate the demand of a higher rent than his wages justify. The landlord from a purely business point of view is surely entitled to the return on his capital which he has left invested in the land to the great benefit of those who require work, and he cannot be held responsible for the maintenance of the ever-increasing families of his workpeople. He may build small cottages and he may build large cottages, but it is always at the option of the labourer to choose between them according to his means. In dealing therefore with the varying rate of wages it is necessary to evolve a series of classes which shall be applicable to cottage building, providing when required the smallest and least expensive type and as required a larger type for those who are able to afford the economic rent charged for them. The smallest type of cottage is at the present moment the one of greatest importance, and the endeavour of to-day is to build such in a way which adequately houses the occupant

and his family and at the same time of such a cost that the landlord is enabled to charge a rent which is at once economic and compatible with his tenants' wages. There are two forms in which cottages can be built: (1) Two floored; (2) Bungalow. The latter type is particularly to be considered in exposed situations and where land is possible of cheap acquisition, in addition to which the inconvenience of the necessarily somewhat precipitous and awkward staircase is eliminated.

The drawings of the two types will give a fair illustration of what is reasonably possible where conditions are normal, and it will be noticed from the specifications that though no inferior materials are used great care has been taken to leave out anything not absolutely necessary without reducing the comfort. There are one or two points which should invariably be borne in mind when considering the ultimate comfort of the occupants and are as follows :—

1. The kitchen or living room. Used mainly for living and should therefore have the best aspect, i.e. south or south-west. If there be a parlour it is only in occasional use. However, such a room, no matter how small, should if possible be provided, as it is the custom of the class rigidly to set apart one room in the house for the storage of household gods, and in the case where only a kitchen or living room and a scullery are provided, the latter will almost invariably be used as the living room and the former relegated practically to disuse.

2. A larder and fuel store, each of ample size are necessary.

3. In planning the bedrooms due provision should be made for the suitable placing of the beds with relation the doors, windows, and (where provided) fireplaces.

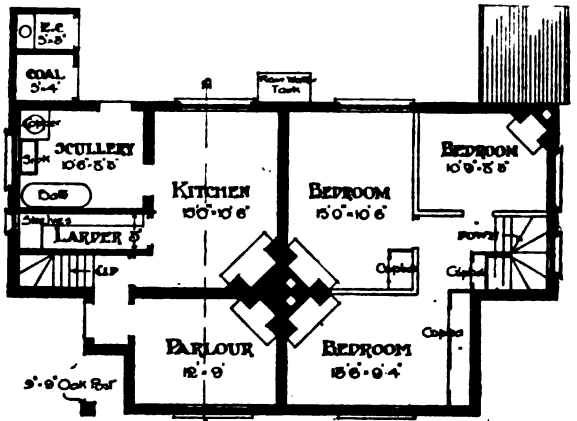
4. In selecting materials preference should be given to those appertaining to the district.

5. Not only from an economical point of view, but also for purposes of cleansing, the floors should be of concrete or good red tiles downstairs, at any rate in the living room and scullery.

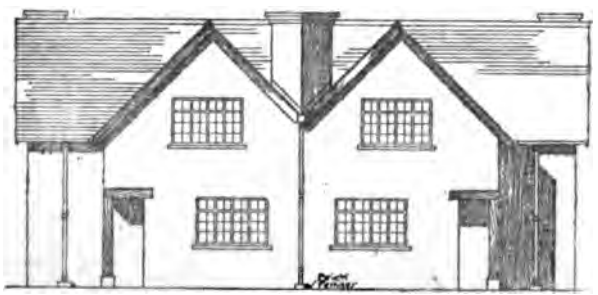
6. There should be facilities for the storage of rain water and such store should be easy of access—that is to say, if possible, pumping should be dispensed with. Even in cases where there is a good supply of well water close at hand it is advisable to collect the rain water, as every housewife will agree as to its value for household purposes. As the first few minutes of a rainstorm will produce unclean water from the roofs of houses it is a very usual custom to provide an inexpensive contrivance which prevents that water from being collected in the storage tank, so that in effect the result is that the roofs are swilled down before the rain they collect passes into the tank. This latter should preferably be of galvanised iron and not the commonly used barrel or water-butt; though the wooden rain water butt is less unsightly it is insanitary and altogether unsatisfactory. The tank should be raised sufficiently above the ground to allow of buckets, &c., being placed under the draw-off tap. A suitable position for this tank will be easily found adjacent to the

Pair of Six-Roomed Cottages.

Scale [graphic] of feet.



Ground and 1st Floor Plans.



Front Elevation.

Side Elevation.

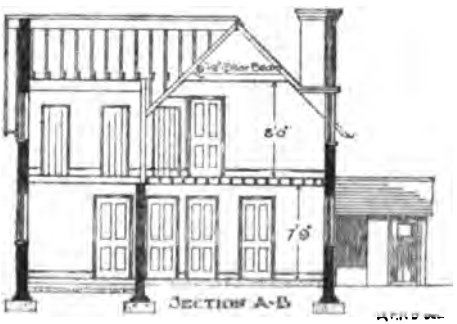
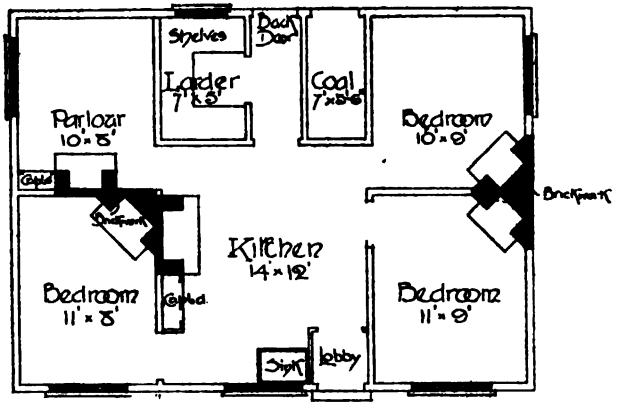


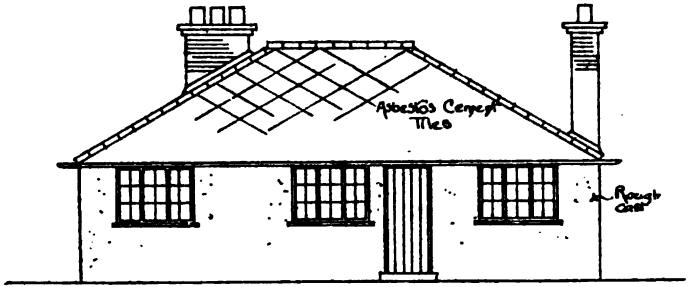
Fig. 218.

FIVE-ROOMED, TIMBER-FRAMED BUNGALOW.

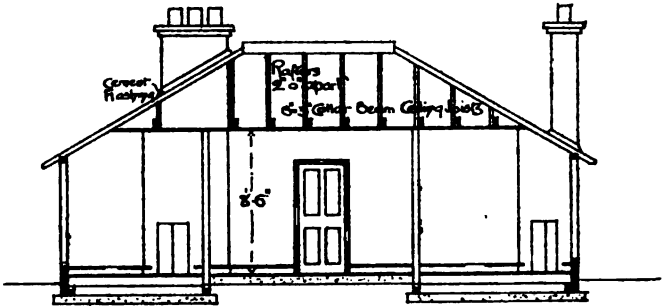
Scale 5 10 15 20 of Feet



PLAN.



ELEVATION.



SECTION.

FIG. 214.

back wall of the cottage without materially altering the arrangement of the back premises.

7. For simplicity, expense, and appearance, casement windows cannot be superseded. These should be constructed in accordance with the local byelaws and, where possible, provided with transoms made to open, which provides for ventilation in all weathers, an advantage which is frequently impossible where casement windows are concerned.

8. A plentiful supply of cupboards is a necessity—another point which wins the grateful approval of all housewives.

9. Another useful provision which makes for the increased comfort of the dwelling is that of a separate wash-house. This need only be of small dimensions and open-fronted so long as it affords shelter, sufficient size for the purpose required, and protection from the cold winds.

10. The general living room which is used the most should be placed so that its windows look on to the road, or at any rate in the direction where most is to be seen.

11. All expense should be directed towards efficiency, not only as regards construction, but also in such matters as unsmoky chimneys, a warm and habitable living room, &c., rather than in adornment.

Approximate cost of pair of Six-roomed Cottages, 15,347 cubic feet at 5*d.* = £319 14*s.* 7*d.*, or about £160 per cottage.

The Bungalow.—This cottage is built in the cheapest possible form, i.e. with timber framed walls upon 4½ inch brickwork. The outside is rough cast, giving a pleasing appearance and at the same time insuring a dry interior. The floors of the kitchen, larder, back passage, and coal store are of concrete, the rest being of timber. The roof is covered with asbestos cement tiles, which admit of a flat pitch and at the same time, being exceedingly light, the number of rafters can be reduced by one-half. The collar beams also act in the capacity of ceiling joists. As shown in the plan it is necessary to build the fireplaces and those of the walls which are in close proximity, of brickwork. The position of the cottage is due north and south, thus insuring the coldest aspect for the larder and that rarely used room, the parlour. All the other rooms get sun from the east and the south.

The cost of this bungalow at 4*d.* per cubic foot works out at £127 14*s.*, so that for about £130 it would be possible to include a small shed with a copper and E.C. in the garden, of timber and galvanised iron, floored in concrete.

CHAPTER XXII

SPECIFICATION NO. 1—CART SHED

General Conditions

Site.—Clear the site of all trees, shrubs, &c., grub up all roots, and prepare for building.

Water.—Provide water for the whole of the work, paying Water Company's charge for same.

Workmanship.—All the materials and workmanship to be the best of their respective kinds, and the contractor is to leave the works in all respects clean and perfect at completion.

Scaffolding.—Provide, erect and maintain, and finally clear away, good and sufficient scaffolding for the use of all trades.

Carriage, &c.—Provide all requisite cartage, carriage, tools, tackle, and every other matter required for the proper performance of the works.

Covering up.—Allow for covering the brickwork during inclement weather, and provide water shoots and any other requisite protection to the whole of the works.

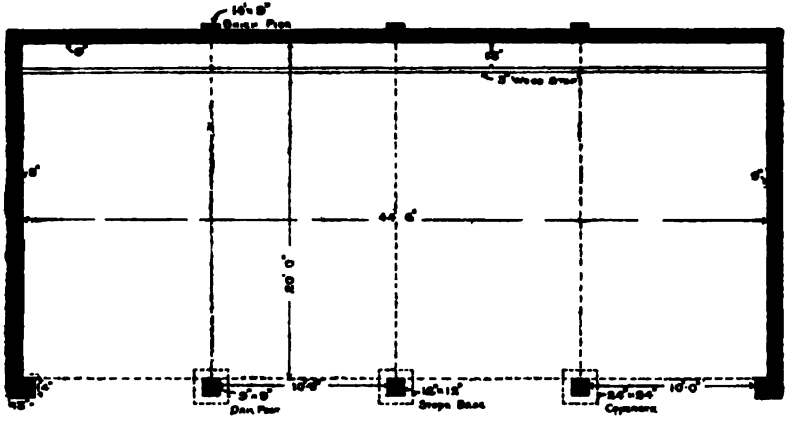
Insurance.—The contractor shall, so soon as the roofs are on, insure the buildings against damage or loss by fire, in an approved office, for the total amount of the contract price, and shall pay the first premium thereon.

Rubbish, &c.—Clear away at completion all surplus materials, rubbish, &c., and leave the shed fit for occupation.

Add to all p. c. (prime cost) amounts and list prices for packing, carriage, profit, and fixing.

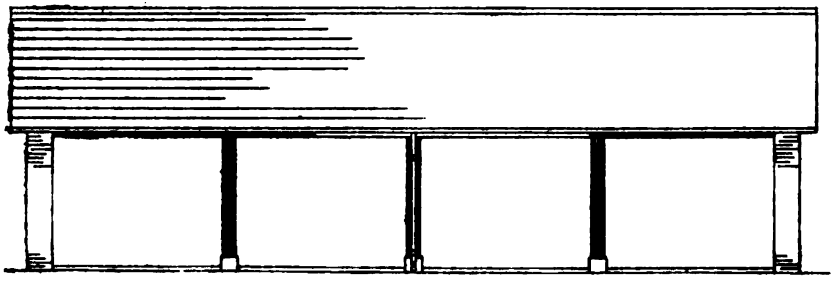
Completion of Works.—The contractor shall give possession of the completed works on the day of , 19 . For every day/week after the said date during which the works are uncompleted the contractor shall pay the employer the sum of £ sterling per day/week as damages.

Defects, &c.—Any defects, shrinkage or other faults which may appear within months from the completion of the works, whether due to defective workmanship or materials or to failure to observe any of the aforesaid covenants, shall be made good by the contractor at his own cost.

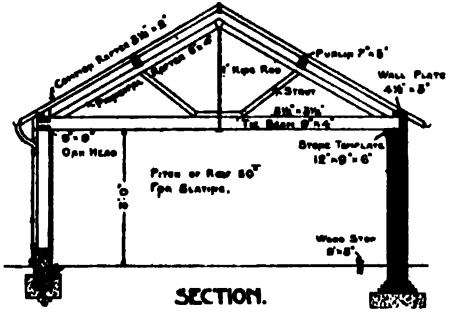


PLAN.

FOUR-BAY CART SHED.



ELEVATION.



SECTION.

FIG. 215.

Excavator and Bricklayer

Excavations.—The earth from the excavations is to be wheeled and deposited and spread on the site where directed.

Excavate the trenches for foundations of walls and posts to the depths and widths shown, fill in and ram earth to footings and stone bases, and wheel and deposit the remainder as above described. Any water that may accumulate in the trenches or excavation during the progress of the work to be baled or pumped out, or otherwise removed from the site.

Concrete.—The concrete for the foundations to be composed of clean sharp gravel or hand-broken bricks in the proportion of one of fresh burnt ground blue lias lime to six parts of aggregate, with a sufficient quantity of clean sharp sand mixed by measure in small quantities, well rammed and properly levelled. Large portions of aggregate to be broken, and none to be larger than will pass through a 2″ ring. Use of 'plums' permitted in foundations, but not at more frequent intervals than one to every six feet.

Bricks.—The bricks to be picked stocks, sound, square, well and evenly burnt.

Lime.—The lime to be obtained from an approved manufacturer.

Mortar.—The mortar to be composed of one part lime as above to three parts of clean sharp sand.

Bed and Point.—Bed all plates and timbers where they rest on or in the brickwork in mortar.

Templates.—Provide and fix concrete template 12″ × 9″ × 6″ to support ends of tie beams and oak head where they rest in the walls.

Pointing.—Point all brickwork inside and out.

Stone Base.—Provide and set Portland or other approved hard stone base 2′ 6″ × 12″ × 12″ with chamfered top edges. Set same 18″ in the ground in concrete. The stone base to be provided with a 3″ × ½″ round galvanised iron dowel let in 1½″ with lead.

Gulleys.—At the feet of the R.W. pipes fix Doulton or other approved stone-ware gullies with galvanised iron gratings, set in blue lias lime concrete, and connect to drain.

Slates.—Cover the roof with approved good quality Countess slates laid to 1″ lap.

Ridge Tiles.—Provide and fix approved half-round red ridge tiles, set and pointed in cement.

Carpenter

The whole of the fir timber for constructional purposes to be the best quality Memel, Riga or Dantzic, sawn die square and to hold the full sizes stated or shown on the drawings.

The oak to be of English growth, sound and well seasoned, and cut from trees which have been felled at least five years.

Only the oak timber to be wrot.
All the timber to be creosoted by the boiling process.
Rafters, &c. (Fir).—The rafters to be $3\frac{1}{2}'' \times 2''$.
The roof battens to be $2'' \times 1''$.
The tie-beams to be $9'' \times 4''$.
The struts to be $3\frac{1}{2}'' \times 3\frac{1}{2}''$.
The purlins to be $7'' \times 5''$.
The wall plates to be $4\frac{1}{2}'' \times 3''$.

Posts, &c. (Oak).—The posts to be $9'' \times 9''$ and mortised at lower ends to fit over iron dowels in stone bases and tenoned at the heads to form joint with oak head.

The head to be $9'' \times 9''$ mortised to form joints with posts and bedded at each end on concrete templates in walls.

Roof Trusses.—Tie-beams of roof trusses to be bedded on concrete templates in walls, and securely jointed to oak heads in front of building.

Wood Stop.—Provide $9'' \times 3''$ wood stop throughout length of building as shown, securely sunk 6" into ground.

Founder and Smith

Eaves' Gutters.—Provide and fix 4" half-round eaves' gutters to front and back roof slopes and cast-iron brackets screwed to feet of rafters. The joints of gutters to be put together with red lead and oakum.

R.W. Pipes.—Provide and fix 3" diameter R.W. Pipes with ears cast on and nails, securely fixed to wall at back and central oak post at front respectively.

Provide necessary swanneck bends and shoes.

Provide $2'' \times \frac{1}{8}''$ W.I. straps where required in roof trusses.

Painter

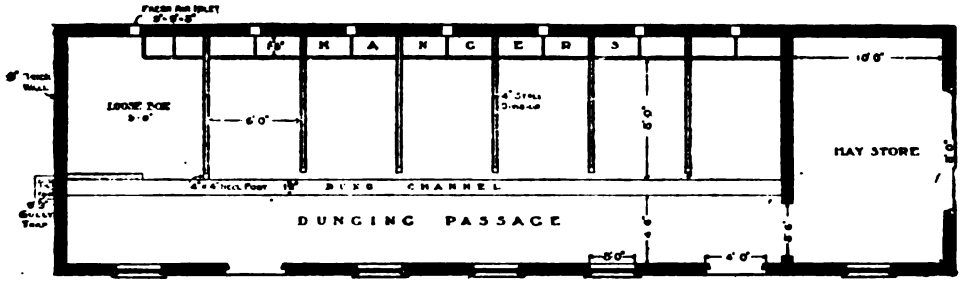
Ironwork.—Scrape and paint four coats on water pipes, eaves' gutters (inside and out), brackets, and W.I. straps with approved tint.

Priced Bill of Quantities for Cart Shed.

For whole Building	£	s.	d.	Per Bay	£.	s.	d.
Excavation.							
Walls and Stone Bases, 22·432 c. yds. @ 2s. . . .	2	4	10	2·84 c. yds.	0	5	8
Concrete (Lime).							
Foundations, 9 c. yds. @ 10s. 6d.	4	14	6	1·185 c. yd.	0	12	5
Brickwork.							
9″ walls and piers 2·726 rods @ £14	38	3	3	0·305 of a rod	4	5	4
Stonework.							
Bases, No. 3, 2½ c. feet @ 7s. per c. foot	2	12	6	each	0	17	6
Templates, No. 5 (12″ × 9″ × 6″) @ 3s. each	0	15	0	each	0	3	0
Timber.							
Oak Posts, No. 3 @ 23s. 6d. (6s. per c. foot)	3	10	6	each	1	3	6
Oak Head, 24·72 c. feet @ 6s. .	7	8	4	6·18 c. feet	1	17	1
Tie Beams (Fir), No. 3 @ 18s. 7½d.	2	15	10½	5·32 c. ft. @ 3s. 6d.	0	18	7½
Principal rafters (Fir), No. 6 @ 5s. 6d.	1	13	0	3·14 c. ft. @ 3s. 6d.	0	11	0
Struts (Fir), 3 c. feet @ 3s. 6d. .	0	10	6	1 c. foot	0	3	6
Purlins (Fir) 21·28 c. ft. @ 3s. 6d.	3	14	6	5·32 c. feet	0	18	7½
Wall Plate (Fir), 8 c. ft. @ 3s. 6d.	1	8	0	2 c. feet	0	7	0
Wood Stop (Fir) 8·34 c. ft. @ 2s.	0	16	8	2·17 c. feet	0	4	4
Roof.							
Including common rafters, battens slates, &c., 13 squares @ £4 10s.	58	10	0	3 squares	13	10	0
Ironwork.							
Eaves' gutters (inclusive 96 feet run @ 8½d.	3	8	0	22 feet run	0	15	7
Rain water pipes, 11 feet run @ 1s.	0	11	0				
Swanneck bends, 2 feet @ 1s. 9d.	0	3	6				
Shoes, 2 feet @ 1s. 3d. . .	0	2	6				
	133	2	5½		26	13	2

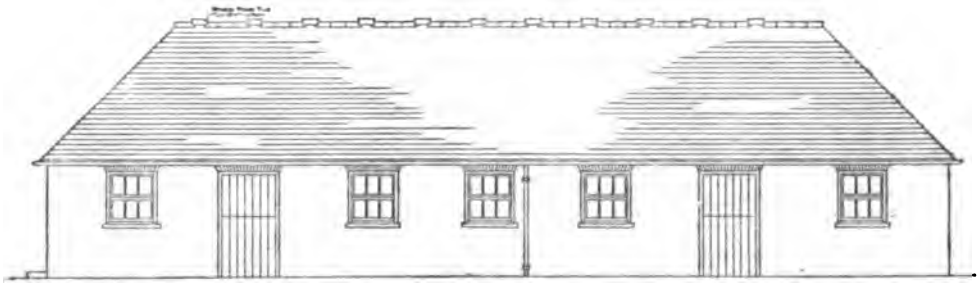
14,360 cubic feet = £133 2s. 5½d.
= practically 2¼d. per cubic foot.

When the cart shed is a dissociated building add £26 13s. 2d. for every bay added and deduct for reduction per bay.

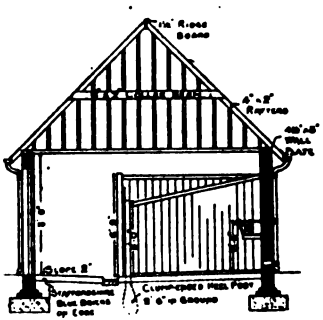


PLAN

SIX STALL STABLE WITH LOOSE BOX . . . .



ELEVATION



SECTION

Fig. 216.

CHAPTER XXIII

SPECIFICATION NO. 2—CART-HORSE STABLES

GENERAL CONDITIONS as in Specification No. 1.

EXCAVATOR AND BRICKLAYER

Excavations.—As in Specification No. 1 omitting all work for stone bases.

Concrete
Bricks for Walls
Mortar
Lime
Bed and Point
Pointing
Gulleys (Rain Water)

} As in Specification No. 1.

Ridge Tiles.—As above. Set every fourth tile in cement with a 2″ overlap on those at each side.

Roof.—Cover the roof with Broseley or other approved red tiles laid to 4″ gauge, each tile nailed with two galvanised iron nails and the heads of the tiles to be bedded in mortar.

Point eaves in cement.

Cutting.—Perform all cutting to hips.

Hip Tiles.—To hips put hip tiles to suit pitch of roof and set and point in cement.

Floor.—Lay over whole of area within the walls a 4″ core of hard dry brick rubbish to receive a layer of 4″ of concrete laid accurately to falls as shown in stalls, dunging passage, and drain channel. The whole of the floor in the stable proper to be composed of approved Staffordshire blue bricks on edge, laid on the concrete bed and jointed in cement. The length of the bricks in the drain channel to run in the direction of the drain channel.

The floor of the hay store to have a surface of 1″ cement floated to a smooth surface.

Relieving Arches.—Build square arches as shown over all door and window openings in front of building.

Turn 9″ two-ring arch over door from stable to hay store.

Cills.—Provide and fix to each window 6″ × 4″ sunk weathered and throated York stone cill.

Damp Course.—Lay through the whole thickness of all walls a damp course formed of two courses of stout slates, laid to break joint, set and bedded in cement.

Limewhite.—Twice limewhite on walls of stable.

Drainage.—Excavate for and lay Doulton's or other approved glazed stoneware socketed rain water and sewage drains jointed in cement, laid to uniform fall of 3 inches in 10 feet and in straight lines from bend to bend. Fill in after the drains are laid, well ram, and spread the surplus earth where directed on site.

Gulley.—Provide and fix gulley at outlet of stable drain. Build brick fender 4½″ high.

Fresh Air Inlets.—Provide to each stall as shown 9″ × 3″ C.I. grating for ventilation.

Carpenter and Joiner

The timber as in Specification No. 1.

Rafters, &c.—The rafters to be 4″ × 2″.

The collar beams to be 6″ × 2″.

The hip rafters to be 6″ × 3″.

The larger door into hay store to be a pair and to be framed and braced 2″ thick and hung similarly to the other doors, provided with box rim lock and furniture.

The door into loose box to be constructed to match the stall divisions with 3½″ × 3″ meeting stile and 4″ × 3″ hanging stile, 5″ × 3″ top, middle and bottom rails, and 4″ × 3″ diagonal brace, close boarded on the outside with 6″ × 1″ boarding securely nailed to rails.

Windows.—The windows to be of deal and 2″ thick, moulded and rebated, the lower half fixed and the top half hinged on 3″ butts at the lower side to open inwards. The jambs and heads and cills to be 4½″ × 3″ rebated.

Ironmonger

Iron Dowels.—To the feet of all door frames put iron dowels.

Holdfasts.—For the door and window frames build in four holdfasts to each, let in and screwed to frames.

Manger Ties.—Provide and fix ½″ galvanised iron manger tie bars connected to halter rings in front and taken through the wall at back and fitted with washers and nuts on the outer ends.

Eaves' Gutters.—As in Specification No. 1.

R.W. Pipes.—As in Specification No. 1.

Glazier and Painter

The glass to be British, the best of its kind, free from all bubbles, and to be well puttied and back puttied.

The painting to be finished approved tints, and well rubbed down between each coat.

Glazing.—The glazing is to be 22 oz. sheet glass.

Ironwork.—Scrape and paint four coats on water pipes, eaves' gutters, and strap hinges.

Woodwork.—Knot, stop, prime, and paint four coats in addition to the priming coat on all woodwork of outer doors and windows.

The wall plates to be $4\frac{1}{2}'' \times 3''$ and to have cement slope from inner edge to top edge of brickwork as shown, to prevent rats and mice.

The roof battens to be $2'' \times 1''$ laid according to gauges of tiles.

Stall Divisions.—The posts to be oak clump-ended and firmly bedded 2′ 6″ in the ground and to be mortised for rails. The rails to be $3'' \times 2''$ (fir) tenoned into heel posts and centre posts and built into walls.

Provide centre posts (fir) $3'' \times 3''$ and bed in ground 2 feet deep. Mortise for rails.

Top rail to be provided with $4'' \times 2''$ capping with rounded edges.

The stall boarding to stop 3 inches from ground and to be $6'' \times 1''$ square jointed and wrot deal firmly secured to rails.

Mangers.—The mangers to be of $6'' \times 1''$ rebated and wrot deal as shown on drawings, the face to slope and the bottom to be laid on $3'' \times 2''$ bearers—3 feet apart—firmly built in the wall.

The top of the manger to be finished with $3'' \times 2''$ wrot and rounded capping, rebated for boarding and fitted with halter ring and tie bar, as shown.

Doors.—The two outer doors of stable to be $1\frac{1}{2}''$ ledged and braced, and hung in two heights bevelled outwards at the centre line to shut close, and hung with bolts and straps and provided with latches top and bottom and bolts on the lower halves. The door posts and head to be $4'' \times 3''$ rebated.

The door from stable to hay store to be similar to above, but 3′ 6″ wide and hung in one height with one latch and no bolts.

(For Priced Bill of Quantities, see p. 314.)

Priced Bill of Quantities for Stables

For Whole Building	£	s.	d.	Per Bay	£	s.	d.
Excavation.							
Walls, 37·70 c. yds. @ 2s. . .	3	15	4	2·77 c. yds.	0	5	6
Site, 106·25 sq. yds. @ 9d. . .	3	19	8	10 sq. yds.	0	7	6
Concrete (Lime).							
Foundations 15·23 c. yds. @ 10s. 6d.	7	19	10	1·11 c. yds.	0	11	7
Stalls, &c., with hard core 89·59 sq. yds. @ 1s. 6d. . . .	6	14	4	13·3 sq. yds.	0	19	11
Haystore with hard core 16·66 sq. yds. @ 4s. 6d. . . .	3	14	11				
Brickwork.							
Walls (less deductions) 4 rods @ £14	56	0	0	0·276 rod	3	17	3
Blue Staffordshire Bricks on edge in stalls 89·59 sq. yds. @ 12s.	53	16	0	13·3 sq. yds.	7	19	6
Timber.							
Stall Divisions, No. 7 @ av. £2 .	14	0	0		2	0	0
Mangers, No. 7 @ av. 15s. . .	5	5	0		0	15	0
Windows, No. 5 @ £2 . .	10	0	0				
Doors, No. 2 @ £2 10s. . .	5	0	0				
No. 1	2	7	0				
No. 1	5	0	0				
Roof (inclusive).							
15½ squares @ £4 10s. .	70	17	6	1½ squares	6	15	0
Ironwork.							
Eaves' gutters, 160 ft. run @ 8½d.	5	13	4	12 ft. run	0	8	6
Rain waterpipes, 12 ft. run @ 1s.	0	12	0				
Swanneck bends, No. 2 @ 1s. 9d.	0	3	6				
Shoes, No. 2 @ 1s. 3d. . .	0	2	6				
Fresh Air Inlets No. 7 @ 1s. 3d.	0	8	9		0	1	3
Gulley Trap (sewage) No. 1 .	0	15	0				
„ „ (R.W.) No. 2 @ 8s.	0	16	0				
	257	0	8		24	1	0

12,725 cubic feet = 4·84*d.* per cubic foot or £36 14*s.* 3½*d.* per stall.
For each additional stall required add £24 1*s.*

CHAPTER XXVII

THE FARM HOMESTEAD

The Block Plan

A few words regarding the accompanying block plan of buildings for a 400-acre mixed farm will, it is hoped, help to banish doubt on any point which may be entertained by the reader.

The North Range has been entirely set apart for the storage and preparation of food, the housing of carts and implements, &c. In fact, all stock-houses have been carefully grouped in other and warmer parts of the plan, thus deriving protection from the North Range, which for the greater part of its length is two-storied, and therefore of great value as shelter from the coldest direction of the wind. Straw barns, as such, may now be considered as practically obsolete, owing to the introduction of the cheaper and more convenient Dutch Barns. It is a very common sight in old farm buildings to see what was originally a straw barn turned into sheep pens, pens for mares with their foals, pig pens, &c., which goes to prove how unnecessary it is to incorporate a special straw barn of expensive height in a modern up-to-date set of buildings.

In the accompanying plan it will be noticed that the calves, though separated by a brick wall, are kept near the dairy herd and the milk-can and weighing and cooling rooms situated conveniently close to a thoroughfare where carts can be brought up close, and to the cowhouse itself whence the milk is derived. The horses both farm and private are provided for in one part and are all together with whatever is necessary for feeding purposes, and the top exit from the farm stables is close by the cart shed. A sufficiency of boxes will be found for normal purposes, in fact there is one box in excess of what is stated by rule of thumb to be necessary. The bull is provided for in a convenient and sunny, yet fairly isolated, spot—a point not always considered in planning farm buildings. Pigs are housed in an entirely separate block of buildings and have nothing to do with the main block, which system is generally recognised by authorities on the subject to be by far the most satisfactory.

It will be noticed that the cost of drains has, as far as possible,

been kept low—that is to say, the least possible amount of underground lengths of pipe are shown, and the necessary inspection chambers indicated.

All the boxes are contained by solid walls, which is an advantage, as they are more likely to be frequently used for calving and for sick animals, in both of which cases isolation and quiet are desirable. The roof of the central cowhouse is a continuous one running from the North Range to the south end of the building and supported at intervals where no cross wall occurs by timber queen post roof trusses. Springing from and supported on brick piers at the same points along the east wall of the cowhouse are the steel roof trusses spanning the covered yard. As regards ventilation, all the stockhouses, stables, boxes, &c., are provided with adequate fresh air inlets in the walls six inches or one foot above the floor level, and with the exception of the dairy cowhouse, outlets for foul air are provided by the system of raising every second or third ridge tile. The cowhouse and the covered yard should be provided with louvres at the apices of the roofs. These may either be continuous or otherwise. The roof covering naturally depends upon the locality, and may be either of tiles or slates, and if economy is to be studied, asbestos cement tiles may well be selected, in which case not only will there be considerable saving in roof timbers due to the lightness of this type of tile, and a flatter pitch possible than in the case of ordinary plain tiles, but a great deal of money will be saved in the actual roof covering itself.

It would be well, in order to keep the eaves of the North Range as low as reasonably possible, to support the roof with a composite roof whose camber gives adequate head room in the centre of each floor. Over the implement shed and the mixing floor, it will be necessary to provide binders, either of timber or steel, in order to form a double floor which will give the requisite strength. As will be noticed, the unavoidable position of one binder end over the door of the implement shed necessitates a cross girder at that point.

It is possible to arrange for enough windows in every separate house or room on the plan, with the possible exception of the dairy cowhouse and calf pens. These can be well provided for by a few roof lights.

As regards the cost of such a block of buildings it is not easy to make a hard-and-fast statement which shall be applicable to every condition. However, by calculating the average cost of farm buildings round about the size of the present case, i.e. for a 400-acre mixed farm, it is fairly near the mark to assume £6 per acre of the area of the whole farm. This gives us a total cost for the block as £2400, for which sum it should be quite possible to erect an extremely adequate set of buildings.

CHAPTER XXVIII

SMALL HOLDINGS

In considering the question of buildings for small holdings we come to an important problem and one which is capable of considerable discussion and argument. One point which is certain is that these buildings must be provided at the smallest possible cost, and at the same time be adequate and suitable for the type of holding concerned. There are three distinct types of production which necessitate individual and peculiar provision as regards the farm buildings themselves, though the farm house will not require to be differently planned except to suit holdings of different acreage. Market gardening, general farming, dairy farming—these three would appear to represent the various requirements.

It should be borne in mind when planning these buildings that future extension may be necessary and the arrangement should be such that additions can be made without great difficulty. The least possible accommodation that is compatible with efficiency should be provided in the first place. This gives a tenant the opportunity of feeling his way as it were and of 'expanding' as he succeeds, instead of falling into the error—one to which human nature is liable—of attempting too much at first and being obliged subsequently to throw into disuse some part of his buildings for which he has nevertheless to pay rent, though deriving no benefit therefrom.

Market gardeners and fruit-growers require the least expensive and smallest sets of buildings, generally comprising a packing-shed, a store, a stable and cart shedding, and an artificial manure and tool store. Unless the holding is very large such buildings can be erected of timber at a cost not much exceeding £100.

The buildings for a holding devoted to general farming are of quite a simple nature, but, of necessity, more expensive than those for market gardening and fruit farming. For a holding of about 30 acres the buildings would comprise a mixing room and fodder store combined, a stable for two horses and a cart shed, a cowhouse, two pig pens and a small store for implements, tools, artificial manures, &c. According to the acreage of the holding so it would be necessary to add to these with loose boxes, extra accommodation

in the cowhouse and the stable. The boxes will be found to serve many purposes, e.g. for calves, extra pigs, fattening beasts, or a sick animal, and therefore their variety of possible utility should be borne in mind when placing them on the plan as regards their desirable or undesirable proximity to the various departments and houses of the rest of the buildings.

A dairy-farming holding, again, will require its distinct type of buildings, since the production of milk and dairy produce will represent the tenant's one principal means of livelihood. This being so, it naturally follows that the regulations drawn up by local authorities under the Dairies and Cowsheds and Milkshops Order will have to be complied with in the matter of cubic air space, lighting, ventilation, storage of milk, cleansing of stock-houses, milk utensils, &c. These regulations more or less simplify the task of planning at the outset, since the designer will go to work in the full knowledge of what has to be in order to ensure their observation. The dairy herd—their accommodation, food factory products and progeny—will, of course, be the question of prime importance; and such, according to the size of holding, will occupy practically all the space to be covered with buildings, leaving merely a few carts and a horse or horses to be provided for. The stable should be situated well away from the cowhouse, as it has been proved that stable odours will put cows off their feed, which will naturally affect the principal product of this particular holding—the supply of milk.

There are one or two points which are of common importance in all the different types of small holding buildings and which must be borne in mind in order to ensure efficiency and satisfactory results.

First of all the buildings, being of what is known as a temporary nature, should be built of timber on dwarf foundation walls 4½ inches thick, and the roofs covered with some inexpensive but effective and lasting material such as asbestos cement tiles, corrugated iron, ruberoid, or something akin to any of these. Asbestos cement tiles from more than one point of view are an inexpensive and eminently satisfactory form of roofing. In the first place they can be supplied and fixed at a comparatively small cost: again, the pitch of the roof can well be not more than thirty degrees, and as the tiles are extremely light the supporting roof timbers may be considerably reduced in size and therefore in expense. The fact that asbestos is a non-conductor renders roof boarding unnecessary.

As can be easily understood, the choice of site will very materially affect the cost of erecting small holding buildings, since the water supply and drainage are vitally important items which must be considered. Preferably the slope of the land should assist in the drainage operation, and some provision made for the collection thereof by means of a sewage tank, whose watertight condition, however, must be above suspicion. A good water supply is absolutely necessary, and if such cannot be provided in the cheapest and most ideal way—that of gravitation—it is possible that a well

may have to be sunk. If this well is to provide drinking water for the house in addition to being used for all purposes in the stock-houses it is desirable—nay, even necessary—for it to belong to the type known as 'deep,' which means that a water-bearing stratum of rock must be reached and the surface and subsoil water excluded. A 'shallow' well derives its supply of water from the surface and immediate subsoil, with the result that the water obtained is very little dissimilar to rain-water, whereas the supply from a 'deep' well is pure and 'hard.' Where it is possible to supply two or three farms from one point and a suitable stream can be used in the near vicinity an hydraulic ram is one of the cheapest, most effective, and satisfactory methods of supply

The cost of the necessary buildings for a fair-sized small holding of about 50 acres should not exceed £300–£350 for the house and £400–£450 for the other buildings, otherwise the tenant will have, for economic reasons, to be charged a rent greater than his holding warrants.

The drawings given herewith are for a general farming holding of about 50-60 acres, and will give a clear idea of the method of construction advisable in this class of work. It will only be necessary to alter the internal accommodation to suit the particular type of produce in which the tenant intends to traffic for a living. An inclusive method of working out the approximate cost of these buildings is by calculating the cubical contents throughout including the covered yard, and reckoning an average of 2½*d.* per cubic foot.

50895 cubic feet at 2½*d.* = £530 3*s.* 1½*d.*

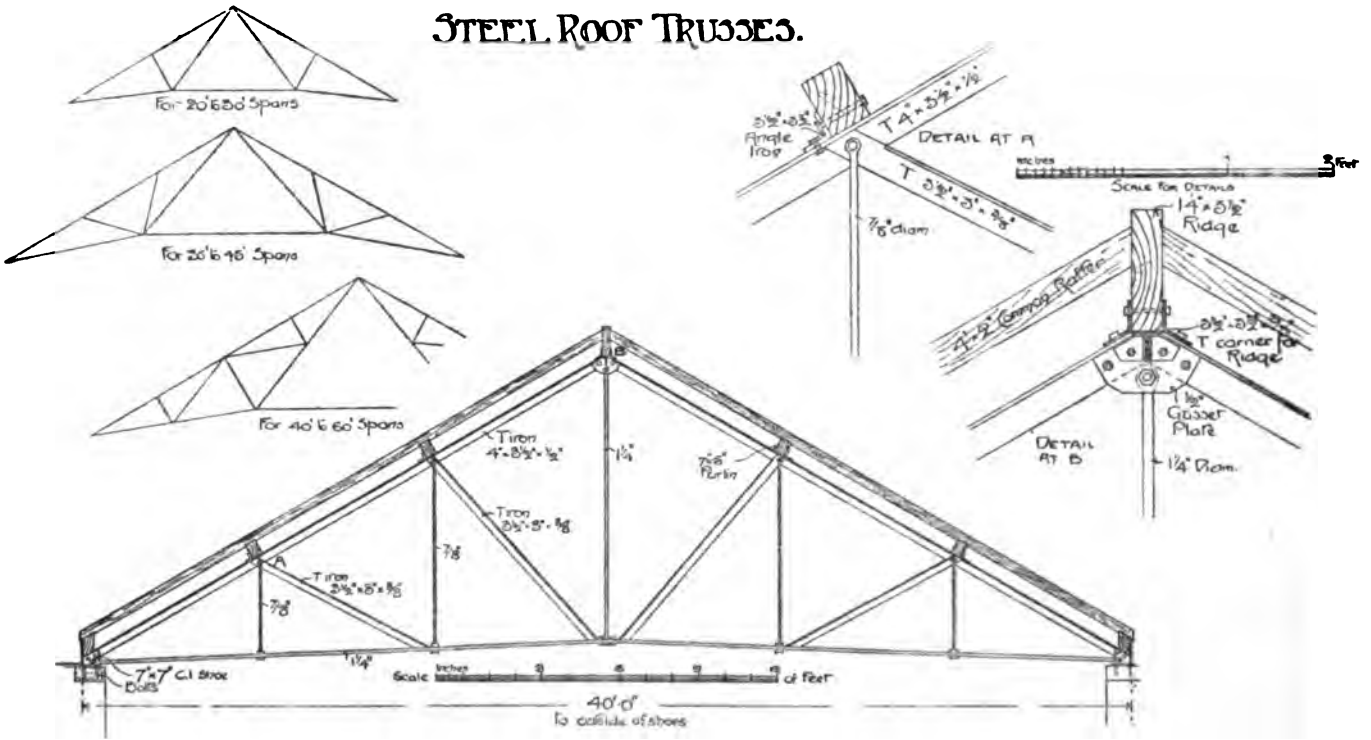

Steel Roof Trusses.
For 20' to 30' Spans
For 20' to 40' Spans
For 40' to 60' Spans
Detail at A
Detail at B
Scale for Details
Ridge
Corner Purlin
T corner for Ridge
Gusset Plate
Angle Iron
Purlin
Tiron
Scale
40'-0"
to outside of shoes

Fig. 222.

CHAPTER XXIX

STEEL ROOF TRUSSES

ALTHOUGH it is possible to substitute steel for timber in roof trusses, no matter how small the span, it will generally be found more satisfactory to employ timber for all spans not exceeding 35 feet. From that measurement upwards the advantage in using steel increases for the following two important reasons :—

1. When the span is greater than 35 feet, the timber members of a roof truss are necessarily large in scantling and therefore expensive.

2. Large scantling means a ponderous and somewhat overwhelming appearance, whereas, even in very big spans, a steel roof truss can be constructed so as to present quite a light effect.

Another distinct advantage which steel has in such work over timber is the possibility of construction with a camber, i.e. the vertical distance from the level of the top of the template to the underside of the tie bar, giving a great deal more head room. This is impossible in a timber roof truss of considerable span as the tie beam has to rest upon the templates at a level which must be maintained from wall to wall.

The covered yard, therefore, is in all probability the only span throughout the buildings for a farm of reasonable acreage where any great advantage will accrue by the use of steel in the roof trusses. This span will, of course, vary with different plans from about 35 to 50 feet. Taking 40 feet as a fair average span, the accompanying drawing of a steel roof truss with all its details furnishes a typical example, in design and scantling, of a suitably constructed truss. It will be noticed that the principal rafters and struts are of T-section, the former being a little larger than the latter. The king rod and the smaller queen rods are simple bars of circular section. At the points where the rods and struts are fixed to the tie rod, which is also of circular section, the latter is forged into nearly rectangular bulges through which bolt holes can be drilled without weakening the rod as would be the case without the extra width provided by the bulge. The heads of the king and queen rods are forged with eye-holes to provide the necessary fixing position for bolts. For as far as the struts lie up

against the web of the principal rafter the flanges can be cut away. Similarly at the feet, in order to secure the struts to the bulge provided in the tie rod, the web is cut away and the flange bent upwards exactly to suit the angle which the camber gives to the tie rod. At the junction of the principal rafters and the head of the king rod, a gusset plate is inserted whose upper edges fit in closely underneath the flanges of the principal rafters, providing a very satisfactory and secure fixture for the three members at the apex of the truss. To provide for the fixing of the timber portion to the trusses as they pass over, short pieces of the angle iron, equal in length to the width of the flange of the principal rafter, are first bolted in position, the purlin afterwards being bolted to the vertical parts of the angle irons. The purlins are, of course, placed immediately over the struts. Similar provision is made for the fixing of the ridge board, except that it is supported on both sides by short lengths of angle iron.

The whole roof truss springs from shoes to which the feet of the principal rafters and the ends of the tie rod are bolted. These shoes are set on stone or concrete templates built into the walls, and secured thereto by means of bolts previously let in with cement. As will be understood, such trusses vary in weight according to the sizes of the various members, and although it is possible to estimate fairly accurately the total cost from the total weight, the cost is more correctly found by working out the individual weight of each type and size of member and applying the price per cwt. as quoted in merchants' price-lists. The cost per cwt. varies according to the amount of labour required to produce steel members of different sections. Thus, bars of circular section are not as expensive, weight for weight, as those of T or H section.

The small single line diagrams will show a few of the trusses of different construction applicable to certain spans. All but those with a camber have been omitted.

The total cost of steel roof trusses, made up as shown in the drawing, and including all necessary parts, junctions, &c., and fixed complete is *27s. 6d.* per cwt.

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